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ABSTRACT

This annual publication contains 43 research papers on a variety of issues related to science education. Topics include the following: mature-age students; teacher professional development; spreadsheets and science instruction; the Learning in Science Project and putting it into practice; science discipline knowledge in primary teacher education; science, technology, and society; gender differences in choosing school subjects; history of science education; quality of teacher education; science attitudes; socially constructed learning; and conceptual development. Other papers concern such areas as report writing; history of science; the nature of science; investigation skills; pseudo-scientific and paranormal beliefs; language in science; concept mapping; constructivism; metaphors; textbooks; children's interests; Aboriginal science; and science and television. (PR)

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Volume 21
1991

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Research In Science Education

Volume
21
1991

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Selected refereed papers from the Twenty-second Annual Conference of the Australasian Science Education Research Association, organised by the Queensland University of Technology, held in Surfers Paradise, Q., 11-14 July, 1991.

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A NOTE FROM THE GENERAL EDITOR

At the time I accepted appointment as Editor of RISE for three years at the Perth ASERA conference in 1990, I expected to be taking study leave in the first half of 1991, which would have meant my absence from the Surfers Paradise conference. However, I expected to be back in Australia in time to supervise the editorial process in the latter half of the year.

My faculty curiously decreed however that the staffing needs of Monash were somehow more pressing than the editorial needs of RISE, and I had to postpone my travels for six months. This meant that I was able to attend the ASERA conference. (I flew overseas out of Brisbane immediately afterwards). It also meant finding some willing colleagues to deputise for me while I was away.

Fortunately, two very able people, Helen Forgasz and Jeff Northfield, readily took on the work. I did not anticipate, and neither did they, the magnitude of the task awaiting them. Although the number of papers published in RISE has grown steadily over the years, in 1991 it took a quantum leap upward to an amazing new level. I, and all of us in ASERA, therefore owe a tremendous debt of gratitude to Helen and Jeff for the very demanding work they have done, and to the expanded Review Panel whose contributions have helped ensure that RISE remains a quality publication.

Paul Gardner
February 1992.

EDITORIAL COMMENTS

During Paul Gardner's absence on leave, we took on the task of putting together this issue of RISE. Our task was greatly facilitated by our secretarial and technical assistants whose previous experience proved invaluable. We also gratefully acknowledge the cooperation of the contributors and reviewers who, on the whole, provided copy in the correct format and met our strict deadlines.

The very large number of papers submitted to RISE this year tested the limits of the publication. We attempted to publish as many as possible. In so doing we decided to extend the reviewing panel and drew heavily on the membership of ASERA to spread the load; in all, 78 people reviewed the papers contained in the following pages.

During 1991 the first monograph derived from RISE was produced:

> Northfield J. R. & Symington, D. (Eds.) *Learning science viewed as personal construction: An Australian perspective.* Curtin University of Technology.

A second monograph, focusing on primary science education is in preparation. An updated cumulative index, RISE 1971 - 1991 has also been prepared and is available from Jeff Northfield, Faculty of Education, Monash University, Clayton, Vic. 3168.

The contents of this issue provide a good indicator of the level and scope of research activity in science education across Australasia. Amongst the papers several common themes are evident: pre-service teacher education, primary science, professional development, and effective pedagogy. Research direction would also appear to have been influenced by the findings of the 1989 DEET *Discipline review of teacher education in mathematics and science.* Science education in Australasia should be strengthened by the research findings, successful innovations and promising initiatives reported in these pages.

Helen Forgasz
Editor,
Jeff Northfield
Assistant Editor.

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White, R., & Tisher, R. (1986). Natural sciences. In M. C. Wittrock (ed) Handbook of research on teaching (3rd edn) New York: McMillan.

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Research in Science Education, 1991, 21, 1 - 9

MATURE-AGE STUDENTS - HOW ARE THEY DIFFERENT?

Ken Appleton
University of Central Queensland

ABSTRACT

Mature-age students have formed a significant proportion of pre-service students in primary teacher education over recent years. Academic staff have reported a difference between mature-age students and school-leavers, particularly in motivation and achievement. This report examines part of a study which explored mature-age students' views about aspects of teaching science and technology, compared to the views of students who came to university straight from school. It examines, in particular, students' personal feelings of adequacy in teaching science and technology in primary schools.

INTRODUCTION

Universities in Australia consistently reserve at least ten percent of places in primary teaching education programs for students over the age of twenty-one years. In some years, this percentage has risen as high as thirty percent. These students are typically called mature-age students, although their ages may range from twenty-one to around forty-five years, sometimes greater. They are typically selected using general aptitude tests and interviews. The remainder of the students are drawn from school-leavers using selection criteria based on school performance (normal entry). They generally fall into the seventeen to nineteen year age range.

This report examines the differences between mature-age students and school-leavers, in their beliefs and feelings about teaching primary science. Academic staff have noticed differences between mature-age students and school-leavers, and some differences, such as greater motivation, and higher levels of achievement (Skamp, 1989) have been reported. Skamp (1989) found no differences between mature-age students and normal entry students in attitudes to teaching primary science, an aspect investigated in this report.

BACKGROUND

All students enrolled in their first year of a three year pre-service primary teacher education course at the University College of Central Queensland were surveyed in the first week of the second semester. There were 139 respondents, 41 (29.5%) of whom were mature-age entrants to the course. There were 31 (75.6%) female mature-age students, and 82 (83.7%) female school-leaver students. The students had not studied science or technology education units at this time, and had completed ten days practicum. The majority of students were drawn from Central Queensland.

PROCEDURE

The survey used was adapted from that developed by Kirkwood, Bearlin and Hardy (1989) for the Primary and Early Childhood Science and Technology Education Project. Most items were Likert-style rating scales, with space to write comments, and explored the students' perceptions about primary science and technology. Perceptions explored included the students' own interest in, and competence to teach, these curriculum areas; the importance of science in primary and early childhood; desirable teaching strategies; and gender issues. An attitude to teaching science scale (Note 1) was also included.

Student responses were scored, and the non-parametric Mann-Whitney U-Wilcoxon Rank Sum W test was conducted to identify items where mature-age students' responses were significantly different from the responses by school-leaver students. To facilitate interpretation of results, means and standard deviations are presented in the tables of results.

RESULTS

The mean and standard deviation for selected items, for each group, are presented in Tables 1 to 4, with levels of significance indicated. Table 1 includes items related to the students' personal perceptions of their own teaching of science or technology. In Table 2, students' opinions about the importance of science to different year levels of schooling, and to boys and girls, is indicated. Table 3 summarises the students' views about the frequency with which particular teaching strategies should be used in science teaching. In Table 4, the perceived importance of a range of reasons for including science and technology in early childhood and primary curricula is indicated. All these tables compare the mature-age students to school-leaver students, showing means and standard deviations for each group on a five-point rating scale, with one the highest rating. The attitude to science teaching scale also reveals a significant difference between the mature-age group and the school-leaver group, as shown in Table 5. The mature-age students, with a lower score on the scale, tend to show a more positive attitude to teaching science than their school-leaver colleagues.

From the tables of results it can be seen that, for this sample, mature-age students compared to school-leaver students:

- are more interested in teaching life and earth topics;
- are less confident regarding the adequacy of their background knowledge for teaching both science and technology, particularly the science areas of energy, matter and space;
- feel more competent to teach technology;
- attach greater importance to teaching both science and technology to all year levels, except for technology in Years 5-7;
- attach greater importance to teaching both science and technology to both girls and boys;

- would put less emphasis on teacher-led discussions and teacher explanations in teaching science;
- would put greater emphasis on providing practice in problem solving, and on showing how science is related to everyday life;
- have a more positive attitude to teaching science.

Table 1 also reveals that, for both mature-age students and school-leavers, students' confidence in their background knowledge to teach the physical sciences is lower than their confidence to teach the life/earth sciences. This finding is consistent with other reports (such as DEET, 1989).

TABLE 1
COMPARISON OF GROUP RESPONSES
PERSONAL VIEWS OF TEACHING SCIENCE/TECHNOLOGY

Survey Item	Mature-Age Mean; St Dev	Sch.-Leavers Mean; St Dev
Level of interest in teaching life topics	1.5 ; 0.7	1.9 ; 0.8*
Level of interest in teaching energy topics	2.3 ; 0.9	2.6 ; 0.8
Level of interest in teaching matter topics	2.6 ; 0.9	2.8 ; 0.7
Level of interest in teaching earth topics	1.5 : 0.6	2.0 ; 0.8*
Level of interest in teaching space topics	2.0 ; 0.9	2.2 ; 1.0
Background knowledge for teaching science	4.0 ; 1.1	3.4 ; 0.8*
Background knowledge for teaching technology	4.1 ; 1.1	3.8 ; 0.9$^{\#}$
Background knowledge for teaching life topics	3.0 ; 1.0	3.0 ; 0.8
Background knowledge for teaching energy topics	3.9 ; 0.9	3.4 ; 0.9*
Background knowledge for teaching matter topics	4.0 ; 0.8	3.6 ; 0.9$^{\#}$
Background knowledge for teaching earth topics	3.3 ; 1.1	3.1 ; 0.8
Background knowledge for teaching space topics	3.7 ; 1.0	3.3 ; 0.9$^{\#}$
Competence in teaching science	2.4 ; 1.1	2.6 ; 0.8
Competence in teaching technology	2.6 ; 1.2	3.0 ; 0.8$^{\#}$

$^{*}P < 0.01$; $^{\#}P = 0.05$

The ratings were on a five point scale, with one the highest rating.

TABLE 2
COMPARISON OF GROUP RESPONSES
YEAR LEVELS AND GENDER

Survey Item - The importance of teaching:	Mature-Age Mean; St Dev	Sch.-Leavers Mean; St Dev
science to Years P-2	2.3 ; 1.1	3.1 ; 1.1*
science to Years 3-4	1.8 ; 1.0	2.4 ; 0.8*
science to Years 5-7	1.4 ; 0.9	1.6 ; 1.0$^{\#}$
technology to Years P-2	2.8 ; 1.2	3.3 ; 1.1$^{\#}$
technology to Years 3-4	2.1 ; 1.0	2.7 ; 1.0*
technology to Years 5-7	1.6 ; 0.8	1.9 ; 1.1
science to girls	1.4 ; 0.6	1.8 ; 0.8*
science to boys	1.3 ; 0.5	1.8 ; 0.8*
technology to girls	1.5 ; 0.6	1.9 ; 0.9$^{\#}$
technology to boys	1.4 ; 0.6	1.8 ; 0.9*

*P< 0.01; $^{\#}$P=0.05.
The ratings were on a five point scale, with one the highest rating.

TABLE 3
COMPARISON OF GROUP RESPONSES
TEACHING STRATEGIES

Survey Item - The amount of time teaching science should involve:	Mature-Age Mean; St Dev	Sch.-Leavers Mean; St Dev
teacher led discussions	2.9 ; 0.8	2.5 ; 0.9$^{\#}$
teacher demonstration	2.3 ; 1.0	2.0 ; 0.9
teacher explanation	2.3 ; 1.1	1.9 ; 0.9
media presentation	2.7 ; 0.8	2.7 ; 0.9
guest speaker	3.0 ; 0.9	3.1 ; 0.9
children doing teacher-led activities	2.5 ; 1.0	2.2 ; 1.0
children doing own activities	1.7 ; 0.6	2.0 ; 0.8
children discussing in small groups	1.8 ; 0.8	1.9 ; 0.7
children doing directed written work	3.4 ; 0.9	3.1 ; 0.9
children doing own assignment/project	2.1 ; 0.6	2.3 ; 0.9

$^{\#}$P=0.05
The ratings were on a five point scale, with one the highest rating.

TABLE 4
COMPARISON OF GROUP RESPONSES
REASONS FOR INCLUDING SCIENCE/TECHNOLOGY IN THE CURRICULUM

Survey Item - the importance of these as reasons to include science/technology in the curriculum:	Mature-Age Mean; St Dev	Sch.-Leavers Mean; St Dev
to interest children in science	1.7 ; 0.8	1.9 ; 0.9
to provide scientific knowledge	2.1 ; 1.0	2.1 ; 0.9
to provide practice in manipulative skills	2.3 ; 0.8	2.4 ; 0.9
to provide practice in verbal communication	2.2 ; 1.0	2.4 ; 0.9
to provide practice in written communication	2.5 ; 1.2	2.7 ; 0.9
to provide practice in problem solving	1.6 ; 0.8	2.0 ; 0.8*
to develop social skills	2.0 ; 0.9	2.1 ; 0.9
to prepare children for further science education	1.9 ; 0.8	1.9 ; 0.9
to show how science is related to everyday life	1.3 ; 0.5	1.6 ; 0.7*

*P< 0.01
The ratings were on a five point scale, with one the highest rating.

TABLE 5
COMPARISON OF GROUP RESPONSES
ATTITUDE TO TEACHING SCIENCE SCALE

Student Group	Mean	St. Dev.
Mature-age	21.0	7.4
School-leaver	24.3*	7.0

*P=0.02
Possible score range was 8 to 56, with a lower score showing a more positive attitude.

DISCUSSION

The results can be summarised by focusing on three main issues:

* attitudes to teaching science,
* self-confidence in teaching science and technology,
* the perceived importance of science and technology to an overall education.

With respect to the first issue, compared to school-leavers, the mature-age students show a more positive attitude to teaching science overall, and are more interested in teaching obviously environment-based areas of science (life and earth). Regarding self-confidence in teaching science and technology, the mature-age students tend to be less confident about their background knowledge than the school-leavers for both science and technology, and show less confidence in the specific areas of energy, matter and space - the areas not obviously related to the environment. Finally, the mature-age students attribute greater importance to science and technology in the curriculum than do the school-leavers.

Mature-age students generally tend to show signs of uncertainty about commencing tertiary studies after several years away from schooling, so their lack of confidence about their background knowledge to teach science and technology could be anticipated. Conversely, in the course of daily life, they would have had contact with environmental issues. Further, many would have their own families, and could understandably have a concern for, and interest in, environmental issues. They therefore could be expected to be fairly confident about environmentally-related content areas, compared to content areas they may not have touched since their own school days. School-leavers, on the other hand, would have had more recent contact with most science content areas. Because of concern for their children's welfare, those students with families could be expected to more highly value the inclusion of science in the curriculum compared to students who have not yet started their own families.

Implications for teacher education

Mature-age students appear to have some advantages over school-leaver students with respect to science teacher education:

- they have a greater interest in teaching certain aspects of science, specifically, the life and earth sciences.
- they recognise the importance of science and technology education to all children.

A disadvantage for them is that, compared to the school-leavers, they lack confidence about their background knowledge in the physical sciences. However, as noted above, Table 1 also shows that the school-leaver students feel less confident about their background knowledge in the physical sciences compared to the life/earth sciences. This overall weakness in the physical sciences has also been noted by others (DEET, 1989), who suggest that science teacher education courses need to target the physical sciences as an area in which all students need to develop confidence. These findings suggest that this should be done particularly for mature-age students. Similarly, technology education needs to be specifically targeted. Both groups of students were less confident about technology education than about science education; though the mature-age students felt more competent to teach this than the school-leavers.

Within the limits of regional cultural differences, the students in this survey would be typical of students entering pre-service early childhood and primary courses. Within this context, the data provide some indications as to how to maximise the science education opportunities for mature-age students in particular, and perhaps for school-leavers as well:

- a focus of students' study in science and technology should be on a technological development based on the physical sciences, which is fairly familiar to the students' environment. The most obvious examples would be household objects which use principles of physics, such as cookers, irons, toasters, light bulbs, heaters and so on. This point is inferred from the mature-age students' greater feeling of competence in teaching technology, compared to their feelings of lack of background knowledge to teach it. As part of their everyday lives they use many technological developments successfully, even though they know little about how they work. The point is also supported by the high rating put on science being related to everyday life by the mature-age students (Table 4).

- the importance that mature-age students place on science in the curriculum should be capitalised on. Because these students see science and technology as important inclusions in the curriculum, they could be expected to be more highly motivated in science and technology education classes. This motivation could be "tapped" in class and used to help the school-leavers develop their views of the importance of science and technology. However, there would also need to be a focus on how to include science and technology in the curriculum, so that they fulfil the important roles that these students ascribe to them.

- the focus of science and technology education classes should be on developing problem solving skills, and on science that is related to everyday life. The mature-age students saw these "life skill" aims as being important considerations for including science in the primary school, and they could be expected to identify with similar aims for their own science and technology education. Therefore, the study of traditional science concepts in an extended high school context, or normal tertiary science degree form should not be attempted for these students; a conclusion also reached by Skamp (1989), and supported by findings by Dooley and Lucas (1981). Follow-up interviews with some students reveal that the problem solving should involve students working on problems that seem "real" to them rather than on students choosing algorithms to calculate numerical solutions to problem exercises.

- teaching strategies employed in science and technology education classes should avoid excessive use of teacher explanations and teacher-led discussions. This statement is based on the assumption that students would expect their own teacher education to model, where possible, the teaching approaches they are learning about. The mature-age students do not consider teacher-centred strategies to be as important as others such as children doing their own activities, and children discussing their work in small groups. While the school-leaver students also tend to show a preference for child-centred strategies over teacher-centred ones, the difference is not as marked. As revealed in follow-up interviews, the school-leavers believe that the teacher-centred strategies should be used more frequently because of their common use in the secondary school. This view needs to be countered, and in the classroom the mature-age students provide a ready source of different ideas from peers. It is worth noting that the strategies nominated by the students as those which should be used most frequently are those which would also be nominated by most science teacher educators, and are advocated in primary science curricula (e.g Deptartment of Education, Queensland, 1981).

Summary

A science and technology education unit in a pre-service course for mature-age students should not be a traditional science unit, but should focus on the students working on technology based problems felt to be real by them. The problems should preferably be drawn from the physical sciences, but selected from everyday life experiences and the students' own familiar environment. The most common teaching strategies to be employed should be student-centred, with a lower frequency of teacher-centred strategies. The perceived importance that the students ascribe to science and technology in the curriculum should be built on, where the school-leavers can benefit from the views of their peers. Students should be assisted to recognise how science and technology can be made an integral part of an effective early childhood or primary education.

The above points have been argued for mature-age students, but for practical and pedagogic reasons, could not be used exclusively for them. There is also evidence from aspects of the study not reported, and from similar work reported by Kirkwood et al. (1989) and Bearlin (1990), that these points would apply to all students, not only mature-age students.

CONCLUSION

The above points about science and technology education may appear familiar to some teacher educators, who have already begun to implement such ideas (e.g. Kirkwood et al, 1989). Aspects of them also run counter to recent trends in higher education, where there are demands for greater efficiency in teaching (usually meaning more lectures to larger groups), and for greater emphasis on discipline studies (usually interpreted in science as traditional degree level units). If science and technology education in the early childhood and primary areas are to progress toward the outcomes advocated by DEET (1989), then these trends need to be resisted, and conclusions such as those above incorporated into teacher education programs.

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PROFESSIONAL DEVELOPMENT AND PERCEIVED NEEDS OF SCIENCE TEACHERS

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ABSTRACT

About 100 science teachers in the Sydney Metropolitan West Region were surveyed to determine their professional development needs and the ways in which these needs could be met. The findings provide a ranking of science teacher perceived professional development needs, a list of possible incentives to motivate science teachers to complete inservice programs (in priority order) and an indication of the preferred modes of presentation to meet professional development needs. In general, science teachers stated a preference for professional development related to modern trends in science education directly related to classroom practice. In contrast to recommendations from DEET, science teachers indicated a preference for traditional models of inservice. Data related to preferred mode of inservice indicated significant gender differences.

INTRODUCTION

A number of recent national reports have commented on the need for the professional development of teachers and science teachers in particular (see eg. DEET, 1989; Boomer, 1986, 1988). These reports have identified a variety of issues, including why there is a need for professional development, what constituted appropriate professional development programs, how these may be effectively delivered and what incentives should be provided to encourage participation. Professional development needs that have been identified include updating knowledge and skills in curriculum, science disciplines and pedagogy and the implementation of these.

Short term withdrawal methods of inservice fail to bring about in-school change (Balla & Gow, 1988). Effective means for delivering professional development for teachers involve adult learning principles such as action research and clinical supervision, which require time for interaction and reflection (Eltis, 1987:171). Tertiary institutions have a major role to play through the provision of both award and non-award courses, to meet the need to extensively retrain existing science teachers.

Studies of the possible incentives for participation in professional development include: a desire for associate staff status for cooperating teachers in teacher education programs (Korinek, 1989); exemption from HECS fees (DEET, 1989:135); study leave from the employer (DEET, 1989:139, Mattock, 1989:183); payment of course fees and provision of grants (Mattock, 1989:183).

The concept that the teaching profession will generally hold Masters degrees is being raised. Knapp, McNergney, Herberet and York (1990) suggest that it is too early to require teachers to hold a Masters degree for continued certification, but Turner (1990) sees that it is an inevitable feature of the continuing education of teachers in the future. The effectiveness of extended inservice training, as opposed to one-off activities, was surveyed by Koballa, Crawley, and Shrigley (1990), who found that cooperative action-research type seminars and courses developing reflective practitioners produced positive change in teachers.

Collaborative action research as a means of delivering teacher professional development through universities (in the context of a Masters degree) is supported by comments by Clift, Veal, Johnson, and Holland (1990), Tobin and Fraser (1987) and Boomer (1988). The Discipline Review sees value in universities giving credit for non-award inservice courses to higher degrees (DEET, 1989). Some conditions need to be met in order to ensure viability of these ideals. The intention of universities to provide award courses in science/science education "are unlikely to come to fruition unless teachers are involved in the planning so that the awards meet their needs, and unless the employers provide funding and/or incentives to teachers to participate" (DEET, 1989:133). Such co-operation may be essential, since inservice providers have not always understood the needs of classroom teachers (Kurger, Summers, & Palacio, 1990).

The purpose of this research was to establish the needs of science teachers in the Sydney Metropolitan West Region. The teachers were surveyed for their perceptions of their professional needs and the optimum manner in which those needs could be met.

METHOD

Subjects

Fifty schools were randomly selected from among all government and non-government high schools in the Metropolitan West Region as defined by the Department of School Education in Sydney, Australia. This represents approximately 50% of high schools in the region. Five questionnaires were forwarded to each school and Science Head Teachers were requested to distribute the questionnaire among all members of staff involved in teaching Science. While the authors do not know the total number of teachers of science who would therefore have had access to the questionnaire an estimate of four to five teachers per staff would suggest a total sample of approximately 200-250 teachers.

Ninety-nine responses were received, almost half of the total sample. Fifty-six percent of the respondents represented government schools and the remainder, non-government schools, a representative sample of schools in the region.

Instrumentation

A questionnaire was devised based on the review of relevant literature and the advice of a panel of experts consisting of:

- The regional science inspector and science consultant,
- executive members of the Science Teachers Association of Western Sydney,
- lecturers in science, science education and research methods

The questionnaire was developed to obtain information in four major areas: personal details; perceived needs; preference among a variety of models designed to cater for these needs; and, factors perceived to influence participation in professional development. Personal information included the respondent's age, gender, experience, academic background in education and science, position in school and subjects taught as well as the type of school in which they were employed.

The second area included academic, professional and personal needs. Academic needs referred to additional content and curriculum exposure to science subjects. Professional needs probed for issues related to professional advancement and development and how these might be achieved in part through further training. Personal needs addressed preferences for working individually or with colleagues, preferences for modes of subject delivery and attendance and time requirements to complete modules.

Course types, inservice models, postgraduate degrees and various other models for professional development as well as the likelihood of such models influencing choice on whether or not to proceed were also solicited. Factors such as the location of resources and classes, the scheduling of classes, accreditation for promotion, employer support, intrinsic rewards and availability of leave and release time for professional development were offered as possible desirable options.

The final questionnaire required a number of revisions before it reached a level of clarity and detail which was judged as adequate by the review panel.

Procedure

The questionnaire was posted to fifty randomly selected high schools in the Metropolitan West Region with a request to the Head of Science to distribute the questionnaire among teachers of science subjects. After two weeks, a follow up letter was forwarded encouraging the participants to respond. One final reminder was given by telephone four weeks after the initial request. The Head of Science was asked to collate all School responses and to forward them to the researchers. Data collation and analysis proceeded after eight weeks.

Data Analysis

Each question was initially analysed descriptively to determine the percentage distribution for categories within questions. Cross tabulations were then used to analyse the relationship among selected categorical dependent and independent variables. For example, age, gender and teaching experience may influence the preferred mode of presentation of professional experience programs and the type of formal qualifications sought. This analysis was carried out using SPSS - x (Nie, 1983). Only the significant X^2 values are reported here, and in cases where only dichotomous values for variables are used the corrected Yates formula value is reported.

RESULTS AND DISCUSSION

The sample

The majority of teachers in the sample (52%) had more than 10 years science teaching experience and just over a quarter occupy an executive position in the school. Every teacher surveyed had tertiary qualifications in education but a few (4%) had no tertiary science qualifications. Only a minority had qualifications at the Masters level or higher (in education 5%, in science 5%). Since beginning teaching, about 21% of the sample had completed some qualification in education compared with about 12% in science. In the last 10 years, 35% of the sample had not completed any qualifications in education and 52% had not completed qualifications in science. The teachers sampled varied considerably in the depth to which they had studied the different branches of science. In particular, they are most highly qualified in Chemistry and Biology, less well qualified in Physics and least well qualified in Geology.

The data also support the assertion by DEET (1989:123) that "the majority of teachers who will be in schools in the year 2000 are already there and they need to be given the opportunities to update their knowledge and skills".

Perceived Professional Development Needs

The teachers were asked about their professional development needs on the following dimensions:

- Catering for the needs of students who may be disadvantaged in science.
- Implementing New South Wales Department of School Education (DSE) policies and initiatives.
- Major trends in science education.
- The role of the science teacher in school.

There was a marked variation in the extent to which teachers in the sample perceived they needed professional development to cater for different disadvantaged groups and the implementation of DSE initiatives and policies. For example 60% indicated a need for professional development to cater for the needs of students with non-English speaking backgrounds but only 27% perceived a need for assistance with Aboriginal students. However, the "perceived needs" related to disadvantaged students and DSE policies and initiatives should be interpreted with some caution because:

- although they represent the perceived needs of science teachers across the region, individual schools could be expected to have professional needs which vary markedly from those of the region;
- they should not be interpreted as an indication of a lack of concern for, or commitment to particular groups of students or policies. Some schools may have successfully addressed the particular requirements of some disadvantaged groups or implemented specific DSE policies.

The majority of teachers sampled perceived a need for professional development in the major science education trends: science, technology and society (84%), science for all (68%) and children's science (67%). Most teachers indicated a clear preference for professional development in aspects directly relating to the classroom teaching and learning of science.

By contrast, professional development relating to working effectively with members of staff, promotion and management were less desirable. Inservice relating to self evaluation/appraisal/reflection was unpopular but as these are areas of contention between the union and the DSE, the responses may reflect their attitude to specific DSE proposals. Therefore, their responses may not be an accurate reflection of the perceived value of evaluation, appraisal or reflection.

When asked to rate their interest in attending an inservice course in 30 different topics these trends were clearer and the pattern was repeated. The vast majority of teachers were interested in attending courses on recent trends and new ideas. The next most popular courses tended to be those directly stating a relationship with senior or junior secondary science. This further emphasises the desire for inservice directly relating to new ideas in teaching and learning with demonstrable applications at the 'chalk face'. Teachers showed only moderate interest in teaching skills not specific to science. The only exceptions to this trend were methods for motivating pupils (82%) which was the second most popular choice and basic science teaching skills (33%) which rated second last. Courses relating to management aspects not directly involving classroom teaching were least popular.

The teachers sampled believe that they have the basic mechanisms of teaching mastered to their satisfaction but that they are interested in motivating pupils to ensure a greater engagement of pupils in learning. Yet this aspect of teaching should be a fundamental component of undergraduate programmes. Even ideas which may be directly addressed in preservice courses should be the basis of valuable inservice if they provide an opportunity for teachers to refine and apply strategies and approaches which they deem useful. It may be that only through teaching experience can teachers recognise and internalise some issues which are examined as an undergraduate. Such issues, once identified, may be better targeted in professional development programmes than in preservice courses. Whatever the general implications, teachers specifically feel they need guidance in order to provide the motivation which is essential to meaningful learning.

Modes of Presentation

The teachers sampled clearly indicated that traditional modes of course presentation were most preferred. External studies and evening classes were ranked as desirable by 70% and 62% of respondents respectively. Presentation of some classes in local schools was also regarded as desirable by 70%. Weekend classes and holiday classes were rated as desirable by only 31% and 37% respectively.

The vast majority of teachers sampled indicated a willingness to attend an inservice presented to science staff by a consultant in their school (91%) but fewer teachers were willing to attend an 'all school staff' consultancy (64%). Teachers were very willing to attend inservice courses presented within their region (90%) but were less willing (30%) to attend inservices outside their region.

Consultancy is the most favoured form of inservice. Inservices are most desirable if they are presented locally and address specific subject needs. Clusters and Education Resource Centres may present an ideal forum for such programmes.

Incentives

Teachers were asked to comment on incentives relating to the four main dimensions of costs, course factors, career and school based factors.

All but one of the items listed were positively regarded as incentives by more than 60% of the respondents. The survey responses have been used to rank the 14 listed incentives in order from most to least popular (see Table 1).

TABLE 1
RANKING OF INCENTIVES FOR COMPLETION OF AN INSERVICE COURSE

Incentive offered	% indicating it is a great incentive	Ranking
Expectation that the course will help you to keep abreast of new ideas in science education	93	1
Payment of your HECS fees by the University or your employer	91	2
Expectation that the course will help you to be a better teacher	90	3
Intrinsic interest in particular course	89	4
Course is located at a venue near you	89	5
Increased salary	80	6
Follow up and support for implementation of ideas developed during the course	77	7
Credit towards promotion	76	8
Relief days/time for attendance	71	9
Credit towards a higher degree	68	10
Reputation/expertise of course presenter	67	11
Payment to do course	63	12
Overt support of principal	61	13
Attendance by other members of your staff	41	14

The data appear to indicate that the teachers sampled did not wish to have to pay to do a course but had little expectation that they should be paid to do a course. This is evidenced by the fact that, the second most highly ranked incentive was payment of Higher Education Contribution Scheme (HECS) fees by employer whereas 'payment to do course' was ranked only twelfth.

The DSE already contributes to some inservice programmes and this practice would appear to be valued by teachers. The extension of these contributions to other inservice courses would provide a highly valued incentive, particularly if they were directed towards programmes which teachers perceive to have intrinsic value.

The nature of the course itself provided the greatest incentive with the three statements about the perceived intrinsic value of the course for becoming better teachers being ranked 1st, 3rd, and 4th. The relatively low ranking (7th) of "follow up and support for the implementation of ideas developed during the course" is surprising since such follow up is arguably an essential component of a successful inservice course (Reid et al. in press). However, anecdotal evidence indicates that the quality of inservice 'follow up' within the region for inservice courses has, in the past, been poor. It may be a case of once bitten twice shy!

Increased salary, opportunities for promotion and credit towards higher degrees, all career related factors, provided only moderate incentives. With the exception of the provision of release time (9th) school based factors provided the least incentive with 'overt support of principal' and attendance by other members of staff being ranked last.

Yet, the support of the principal may be essential to the implementation of some inservice ideas. Furthermore, the benefits of another member of staff with a similar inservice experience and local school knowledge could also be regarded as an important ingredient for the successful application of new strategies in the school environment. The attendance at inservice of a number of staff members may provide the 'critical mass' and basis for productive in-school interaction which may be required to bring about in-school change.

Only a minority of teachers expressed an interest in enrolling in higher degrees. Degrees in science were of marginally greater interest than degrees in education. Their ranking in order of interest was M Sc (34%), M Ed (29%), PhD (science 17%), PhD (education 15%).

Intrinsic course characteristics provided incentives for more teachers than extrinsic career or school based factors. The fact that only a minority of teachers indicated an interest in higher degrees may suggest that they perceive that they do not meet their needs. Yet it has been argued that "the need for the continuing education of teachers throughout their professional lives is no longer disputed... The problem is to move from an agreement in principle about the need for continuing education to turning the principle into effective practice" (DEET, 1989, 123).

This effective practice might be achieved by targeting specific needs indicated by science teachers. In simple terms this means that higher degree subjects must provide an opportunity for the practising teacher to explore modern ideas in teaching and learning with an emphasis on their direct application and evaluation in the science classroom.

The data indicate that if teachers are to regard higher degrees as valuable means of professional development then they must be intrinsically valuable and should be financially subsidised by the employer. Higher degree subjects designed cooperatively by teachers, employers and lecturers with a strong action research component may provide the basis for attractive and effective professional development. Such programs would require a significant time and financial commitment on the part of employers, universities and participants but they represent an opportunity to bring about significant change in school science education. The hitherto typically short inservice programs with limited follow up which have tended to dominate professional development, have been unable to provide such change.

Nevertheless, even providing the perfect professional development programme through higher degrees in itself is not enough. Given that only a minority of teachers are interested in such degrees, it is essential that the benefits of the degrees relating to improving science teaching in the classroom be effectively communicated to clients. This may well prove to be the most difficult task.

Relationships Among Variables

There appears to be a marked inherent similarity within the population sampled in terms of their responses to the items in the questionnaire. Opinions diverged on few items. For example, respondents were in general agreement in their responses to 70 of the 82 items. Given the fundamental similarity of the sample few significant relationships were anticipated.

Cross tabulations were used to:

- determine relationships among teacher personal characteristics and the teaching of specific senior science subjects.
- identify any relationships among teacher, school type or gender and the dependent variables.
- identify relationships among the independent variables and the items where opinions seemed diverse.

Experienced teachers are more likely to teach the physical sciences than less experienced teachers (Physics: $X^2 = 8.6, P < .05$; Chemistry: $X^2 = 12.6, P < .01$). This is perhaps not surprising since other data indicate that older teachers (>35 years) tend to have studied physics in greater depth than younger teachers ($X^2 = 12.9$ $P < .05$).

Although there were no significant differences between males and females in their depth of study of the major branches of science, women were significantly less likely to teach physics than men ($X^2 = 10.8, P < .01$).

These results point to two major problems in the future teaching of senior physics. Firstly, there is an aging pool of physics teachers and these are not being adequately replaced by recent graduates. Secondly, although there are no significant differences in their depth of study of physics, men are more likely to teach physics than women and this can only encourage its already masculine image.

The first problem could be addressed through inservice programs designed to provide teachers who do not have a strong background in physics with the knowledge and skills to teach senior physics. The second suggests a need for changes in attitudes which will be more difficult to bring about.

There was no significant differences between government and non government schools on any items except in the area of catering for the needs of physically disabled pupils. A significantly higher proportion of government school teachers ($X^2 = 11.0, P < .05$) expressed a need for professional development in this area.

There were no significant difference between males and females in their stated perceived professional development needs, including needs related to gender issues. However, women differed from men in their ratings of the mode of inservice presentation. In particular, although women did not favour holiday or weekend classes, they found them more desirable than men (Holiday: $X^2 = 7.9, P < .05$; Weekend: $X^2 = 10.11, P < .01$).

If, as the data suggest, women prefer modes of presentation of professional development which are different from men, they may be less able to participate in professional development. This has serious implications for their equal employment opportunity, particularly where promotion may be influenced by the acquisition of higher degrees. Further research is required to examine the particular needs of women to ensure that they are not disadvantaged by the delivery of inservice programmes in ways which they find unattractive.

The position in school and years of teaching experience were significantly correlated with some of the responses to the professional development needs items. As might be expected, executive staff indicated a greater willingness to attend inservice in the areas of staff leadership ($X^2 = 9.1, P < .05$) and supervision of trainee teachers ($X^2 = 8.5, P < .05$).

Relationships between professional development needs and years of teaching experience were less predictable. Teachers with more than 10 years teaching experience tended to be more interested in an inservice course on career motivation and satisfaction in teaching than less experienced teachers ($X^2 = 9.9, P < .05$). Teachers with 2 to 10 years experience were more interested in attending inservice courses related to classroom management for effective learning and motivating pupils than were teachers with less than 2 years experience or more than 10 years teaching experience (effective learning: $X^2 = 10.3, P < .05$; motivation: $X^2 = 9.6, P < .05$).

Teachers with moderate (2 - 10 years) experience, tended to be more interested in some inservice courses than beginning or very experienced teachers. This finding is difficult to explain. Perhaps inexperienced teachers are too busy surviving to consider further professional development in their first few years and that experienced teachers may be set in their ways and no longer readily open to change.

CONCLUSION

There appear to be some significant issues affecting the professional development of science teachers. Those teachers who have passed the survival stage, but who are not yet set in their ways appear to be open to new ideas and willing to invest personal time and energy in courses perceived to have intrinsic value. Courses appear to be most desirable if they contribute directly to improved classroom teaching and are financially subsidised by the employer.

Whatever the reasons, it is apparent that it may be easier to market professional development programs related to improving pupil learning to teachers with more than two but less than 10 years of teaching experience. However, teachers with more than 10 years experience are more likely to be attracted to inservice aimed at providing greater satisfaction in their work. These programs may only require variations in marketing since it is arguable that similar professional development might provide for both; that is, provide job satisfaction by enabling teachers to improve pupil learning.

The stated preference for local and/or in-school course delivery is consistent with comments in the literature supporting collaborative action research as a mode of delivery. The differences indicated by the data between men and women in their preferred mode of delivery of professional development requires further investigation. There is a clear role for university staff to work with high school science teachers. However, in the context of award-bearing courses, universities need to address an image problem. They need to ensure that higher degree courses are not only relevant to clients who wish to improve the quality of their teaching, but also communicate this to them.

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A SYSTEM TO EXPLOIT THE SPREADSHEET 'EXCEL' FOR ENHANCING LEARNING IN SCIENCE

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ABSTRACT

A spreadsheet system is briefly described, that enables students, teachers and curriculum developers to rapidly and easily make use of Microsoft Excel's unique database and graphics capabilities in the Science classroom. This system (known as the Warwick Spreadsheet System) uses Excel's inbuilt macro language to provide a range of facilities that are tailor-made for science applications (rather than the business applications for which Excel was originally designed). These include the automatic drawing of graphs of various sorts and the ability to rapidly write mathematical models of scientific phenomena, using (if desired) ordinary words rather than algebraic symbols. Examples of applications in physics, biology meteorology and astronomy are given. These examples are chosen to illustrate different types of application (e.g. data exploration, simulation, modelling, interactive diagrams). Educational advantages of the system are discussed, particularly as they relate to the possibilities of more open-ended investigations, more problem-oriented activities and a more active learning situation.

INTRODUCTION

The Warwick Spreadsheet System is designed to make the most useful features of the spreadsheet and graphic database, Microsoft Excel, immediately available in the Science classroom with the minimum of familiarity with computers on the part of both student and teacher. At first sight, Warwick spreadsheets look much like fairly normal spreadsheets with three graphs or charts linked to them, but in fact there is much more to them than meets the eye. Instead of the usual Excel commands there are specially written commands, organised into pull-down menus and selected using a mouse. These enable things that would normally take several operations to be done with just one command from the user, (or sometimes two), for example, drawing graphs or bar charts of one quantity plotted against another, superimposing different graphs one upon another for comparison purposes, setting up a quantitative model or simulation using formulae. The whole system is based on Excel's in-built programming language (or 'macro language') that enables large numbers of individual commands to be strung together (and made more general) so as to form a short program (or 'macro'); however, the user is not aware of this, as macros are hidden in memory and only evident by the functions that they perform.

New spreadsheets are set up starting from a 'template' that appears to be a blank spreadsheet, but in fact contains a lot of hidden formulae and cells that are needed for calculating such things as the 'last values' of formulae (see below) and for linking data to graphs and charts. Formulae and numerical (and text) data is entered on the template and a single command then causes the spreadsheet to be automatically set up so that formulae and graphs or charts are calculated correctly using the names assigned by the user for different quantities. In the case of phenomena such as predator-prey interactions and planetary orbits that are calculated step by step as they evolve with time, the usual spreadsheet procedure, of copying the same formulae onto successive rows of the spreadsheet, each new row corresponding to another interval of time, is used. However in the Warwick system, the process is automated.

Rather than explaining the system any further in the abstract, it will be easier to show its capabilities and educational possibilities in the context of specific examples. These examples are all taken from the Warwick Spreadsheet System 'National Curriculum in Science' package, shortly to be published in England by Longman Logotron (Note 1). This contains a range of about thirty applications, as well as the system itself and is aimed mainly at the middle to upper secondary level. The biology examples were written by Dr. John Hewitson of Oundle School (Note 2) and the physics, astronomy and meteorology examples are by the author. Examples in chemistry (not illustrated here) were written by Dr. Mike Stephen, also of Oundle School.

Analysing published data

Obvious applications in this category include data on the chemical elements of the periodic table and climatic data for different locations. Data on the Solar System also make a good example of this type of use (Fig. 1a). This shows sections of a spreadsheet that contain numerical and text information on the planets and major moons of the Solar System and on the largest of the asteroids, Ceres. The student is able to explore these data on screen using the mouse to scroll to different parts of the data and to highlight cells containing text so that their contents appear at the top of the screen. In conjunction with suitably written worksheets, he or she is able to go on a guided voyage of discovery around the Solar System. Some of the things he or she will discover are of a fairly straightforward nature, for example how large the various planets are and how long it takes them to orbit once around the Sun. Others are much more exciting: for example that Venus has such a pronounced greenhouse effect that lead would melt at its surface; that Io, the satellite of Jupiter, orbits so close to its surface that it is continually being flexed by Jupiter's gravity and so heated up sufficiently to have enormous geyser-like volcanoes of molten sulphur and sulphur dioxide gas. Putting the exciting information about the planets and their moons which has recently been discovered by space probes on a spreadsheet gives students a more interesting and active way of 'discovering' it than simply listing it in a book.

However, the real benefit of the system becomes apparent when one is looking at numerical information. Because it can be displayed in a graphical way, students have immediate access to a visual representation of any information that they are interested in. Furthermore, since up to three quantities can be plotted against any other three, either as a bar chart or a graph (or pie chart), correlations are easy to spot between different sets of data. For example, in Fig. 1(b) the first two charts show that in general the mean surface temperatures of the planets decrease as one gets farther from the Sun. However, there is something anomalous about the temperature of Venus. The last two charts, on the other hand, show that the dates at which the different planets (and Ceres) were discovered correlate exactly with their maximum brightnesses in the sky, (a large visual magnitude meaning a small brightness). Questions can be asked to encourage students to discover relationships like these for themselves, and to get them to think of reasons for them. For example, 'Why is Venus so much hotter than one would expect from its distance from the Sun?' This provides a more active involvement in the learning process and a more problem oriented approach, both of which fit in well with a constructivist view of learning science, in which students are seen to be active in constructing their own scientific views of reality, rather than as sponges passively absorbing information from books and teachers.

Well designed worksheets written to accompany spreadsheets can put more onus on students to find out for themselves and in their own way than is possible with static information in books or with most conventional computer programs. These are often more restrictive in the information they provide and the order in which it can be accessed. The Warwick system is intended to transfer more ownership of the learning process to students so increasing motivation and a sense of personal achievement. It is even possible to frame questions in such a way that the learning process becomes completely open-ended, e.g., 'Find the most unusual object that you can in the Solar System', or, 'Imagine that you are the owner of a company some time in the distant future that runs tours around the Solar System. Devise the tour that you think would be of most interest to prospective clients and write a brochure describing what people will see on your tour.'

Analysing Students' Own Data

The system can be used to store, display and analyse any numerical data that a student may obtain, whether it be the results of a laboratory experiment or field data such as weather measurements. All the student needs to do is to give names to the columns that he or she wishes to use for different measurements and for any calculated quantities, together with any formulae that are required, and the system will automatically do the rest, calculating quantites and drawing graphs and charts as required. In the case of weather recording, this might mean having columns for daily readings of maximum temperature, minimum temperature, wind speed, wind direction, cloud cover, rainfall and atmospheric pressure. A further column could then be set up to calculate daily temperature ranges. If the maximum and minimum values were labelled 'max' and 'min' the required formula would simply be '=max-min'. Formulae can use algebraic symbols, ordinary words, or abbreviations (as here). Without the Warwick system one would either have to use so called 'cell references' (e.g. 'C4-C6' or 'C4-C6') or give each cell its own name separately. The system automates the process so that the student has only to enter the required name in the cell above the quantity or quantities to which it refers.

As well as looking at simple charts of daily variations in weather, students could also look for correlations, e.g. compare charts of temperature range and cloud cover to see if clear skies give rise to large daily temperature variations, or plot a scatter chart of temperature range against cloud cover to see if a correlation is apparent. In applications such as these where students are analysing their own data the power of the system is in enabling them to rapidly and easily look at a large number of different aspects in a graphical way. There is no need to spend time either mastering spreadsheet techniques (important though that may be in other contexts) or in carrying out these techniques, which are relatively time consuming and in any case tend to divert the student's attention from the subject matter in hand and onto the computer. With the spreadsheet, system activities that would otherwise require a lot of time and effort on the part of the student become quick and easy to carry out.

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Name	Description	Distance (Earth-Sun = 1)	Orbital period (Earth years)	Diameter (km)	Mass (Earth = 1)	Mean density (g cm^-3)	Surface gravity (Earth = 1)	Visual magnitude at brightest
X2 X1 X3		Y2	Y3					
name		a	T		mass	dens	g	mag
Mercury	planet	0.3871	0.2408	4878	0.055	5.43	0.38	-1.9
Venus	planet	0.7233	0.615	12104	0.82	5.24	0.91	-4.4
Earth	planet	1	1	12756	1	5.52	1	n/a
Mars	planet	1.5237	1.8809	6794	0.107	3.9	0.38	-2.0
(Ceres)	asteroid	2.7671	4.603	1000	tiny		tiny	+7.4
Jupiter	planet	5.2028	11.86	142796	317.8	1.3	2.53	-2.7
Saturn	planet	9.588	29.46	120000	94.3	0.7	1.07	+0.7
Uranus	planet	19.191	84.07	50800	14.6	1.3	0.92	+5.5
Neptune	planet	30.061	164.82	50450	17.2	1.5	1.18	+7.8
Pluto	planet	39.529	248.6	2290	0.002	1.8	0.03	15.1

Io	satellite of Jupiter	Tidal flexing of Io's surface due to enormous gravity of Jupiter causes enormous geyser-like volcanoes of liquid sulphur and sulphur dioxide gas; surface is white, yellow, orange and black due to sulphur compounds and white sulphur dioxide snow
Europa	satellite of Jupiter	Covered with a smooth layer of frozen water criss-crossed by an intricate pattern of long cracks (probably produced by tidal flexing due to Jupiter's gravity)
Ganymede	satellite of Jupiter	Slightly larger than Mercury, largest satellite in Solar System; heavily cratered surface of frozen water; old dark smooth areas and younger light areas with parallel mountain ranges 1 km high
Callisto	satellite of Jupiter	Almost as large as Mercury; heavily cratered dark crust of frozen water

Figure 1(a). A sample of data from a spreadsheet on the Solar System.

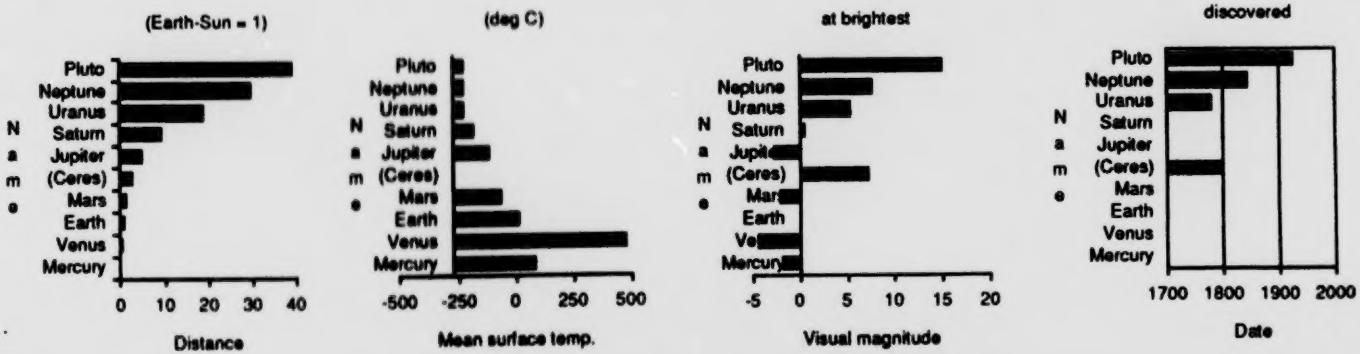


Figure 1.(b). Some specimen charts produced using the spreadsheet in Figure 1(a).

Predator-Prey			John Hewitson		13th May 1991			
		Start Prey Number	Start Predators Number	Refuges Number	Prey Increase Rate	Pred Decrease Rate	Max Prey Number	Time Interval year
		PreyStart	PredStart	Ref	PreyIncRate	PredDecRate	MaxPrey	Interval
		20	5	0	1.00	0.50	10000.00	0.50
Step No.	Year	Prey Increase Number	Prey Number Prey	Pred Increase Number	Pred Number Predators			
	X1 X2		Y1 Y3		Y2 X3			
n	yr	PreyInc	Prey	PredInc	Pred			

Figure 2(a). A spreadsheet to calculate predator-prey interactions.

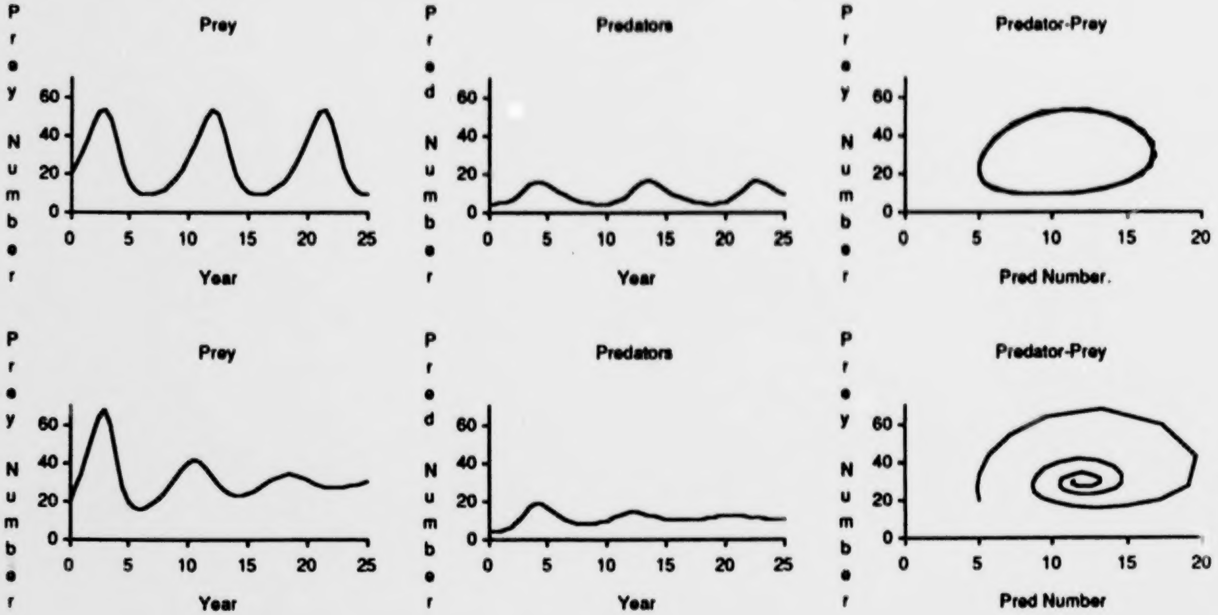


Figure 2(b). Some graphs produced using the predator-prey spreadsheet in figure 2(a).

Simulations and Modelling

Figure 2(a) shows a spreadsheet that calculates predator-prey interactions and Figure 2(b) some specimen graphs produced. This is a good example of a simulation or mathematical model of a scientific phenomenon. There is a spectrum of sophistication in the way that such a spreadsheet can be viewed. At one extreme it can be used as a straightforward simulation, in which students have no idea of the scientific principles on which it is based. By analogy with electronic equipment which often used to be concealed from the user in a black box, such uses are sometimes called 'black box' simulations. At the other extreme it may be the result of a modelling exercise in which students gradually build up the scientific model for themselves by writing suitable formulae with help from the teacher. In between these two extremes students may understand the principles on which a spreadsheet is based without having examined the actual formulae, or they may have examined both the principles and the formulae that have been used (although someone else has actually written them). The exact mode of use on the spectrum between 'black box' simulation and modelling activity depends on the sophistication of the students, their mathematical ability and the aims and philosophy of the course they are following. For further discussion see Gorny (1988). However, it is arguable that for students to have no idea of how the computer is making its calculations is rarely a good idea educationally. Instead the aim should always be for students to understand the scientific processes underlying the phenomena that they are studying. Some simple idea of the assumptions and principles contained in a spreadsheet model is therefore always to be recommended. This can then promote discussion of whether the computer model is a good one and whether it can be improved. Spreadsheets can be written which actually enable the student to examine the consequences of different models. For example in the spreadsheet shown in figure 2 the model can be modified to incorporate the idea that prey often have places where they can hide safe from their predators. These are called 'refuges' on the spreadsheet. This gives rise to quite a different prediction as the lower three graphs show. See Hewitson (1984) for further discussion of predator-prey models.

Educational advantages of simulations and models (with some student understanding of the model at least) include a more active learning style and a greater student ownership of the learning processs as well as the possibility of more open-ended investigations and more problem-oriented activities. These should result not only in greater motivation but also in more effective learning than would be the case where information is absorbed passively from teachers and books alone. A further advantage is that simulations and models can often enable a greater range of phenomena to be studied and in a more realistic way than would otherwise be the case. This is particularly so where there are either experimental difficulties, (any phenomena that are too difficult, too dangerous, too costly, too slow, too fast, or simply impossible in the laboratory), or mathematical difficulties, (for example: ecology, genetics, planetary orbits, projectiles in 'real' situations involving air resistance and winds).

The specific advantages of modelling activities as learning tools have been discussed by many researchers, (for example Ogborn, 1987; Gorny, 1988; Webb & Hassell, 1988; Schecker, 1991), but centre around the idea that constructing models forces students to state their ideas in an explicit form so that predictions can be made and compared with reality. This forces a re-formulation of these ideas by students themselves where they are found to be inadequate.

Producing Visual Aids and Illustrations

Graphical hard copy is useful for students who may wish to include it in their project work and for teachers who may wish to use it for handouts to students or for making overhead transparencies. The advantage of using spreadsheets to produce such materials is that they can be created to illustrate very specific points and tailor made for a particular situation. Often such hard copy may not be available by other means, or it may show ideas in a new light. Fig. 3, for example, gives an instructive view of the relative sizes of the planets' orbits and was produced by a spreadsheet based on simple calculations involving Newton's Second Law of Motion and his law of Gravitation (Beare, 1983). The system allows charts and graphs to be printed out in the usual way, but also has provision for copies to be saved on disc under any name the user may choose, while the original stays on screen with the same name. At a later date, these saved charts and graphs can be recalled and examined on screen, printed out, or possibly copied and pasted into a word processor such as Microsoft Word (which is how most of the figures in this paper were processed).

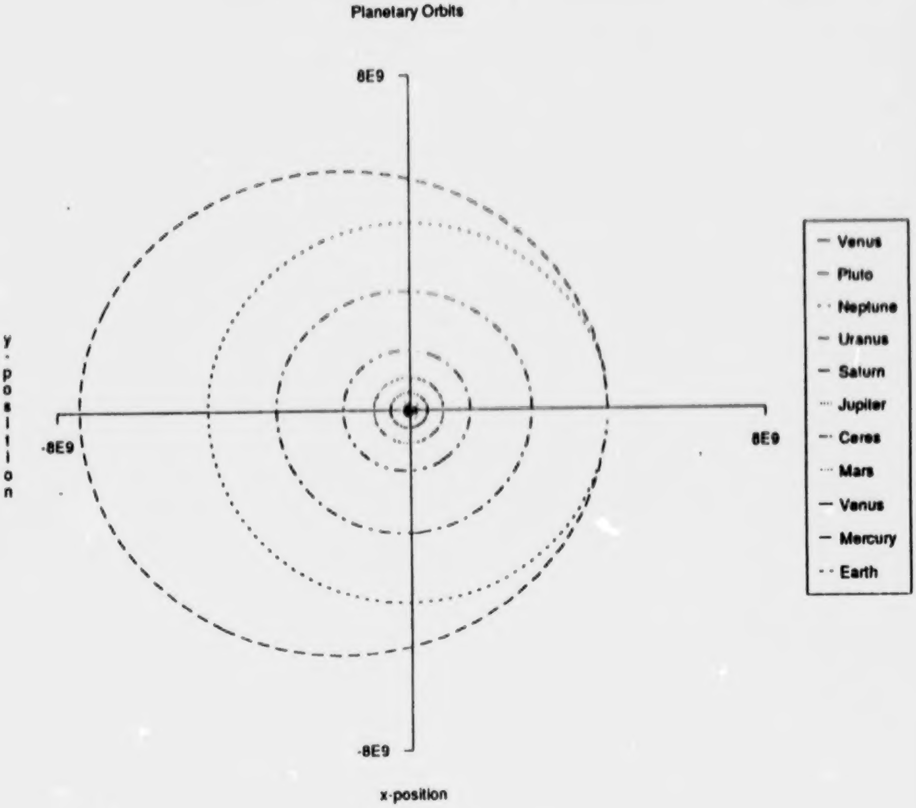


Fig 3. Orbits of the planets produced using a simple spreadsheet.

Interactive Diagrams

Spreadsheets can be created which draw interactive diagrams such as the optical diagrams shown in Fig. 4. Altering any of the following parameters on the spreadsheet results in an immediate change in the optical diagram: object distance, focal length, diameter of lens, height of top or bottom of object. Similar spreadsheets can be written to show light passing through more complex instruments such as telescopes and microscopes and to show rays rather than the edges of beams of light as here. In some ways this type of use overlaps that of a simulation, except that in this case there would be no intention of the student understanding how the spreadsheet works: it would simply be an interactive diagram which would help intuitive understanding to be built up of how light beams behave on passing through a lens.

Other Facilities

Different menus of commands appear according to whether the 'active' window is the spreadsheet or one of the three charts, or whether no spreadsheet or chart is currently open. Up to three pairs of x-y data on a spreadsheet can be plotted at once. Normally these are dynamically linked to the parent spreadsheet so that changing data on the spreadsheet causes an immediate change in the associated graphs and bar charts. The user has the option of plotting these on separate 'charts' or of plotting them all on one, e.g. for comparison purposes. A 'Fix plot' command allows the currently plotted data to be 'fixed' on the chart(s); subsequent changes on the spreadsheet then result in the new data being plotted on top of the fixed data. A large number of plots can be fixed on one chart in this way (as with the planetary orbits in Fig. 3). Also a facility is provided for drawing a least squares linear or exponential fit through a set of data points, this being particularly useful when students need to analyse their own experimental data.

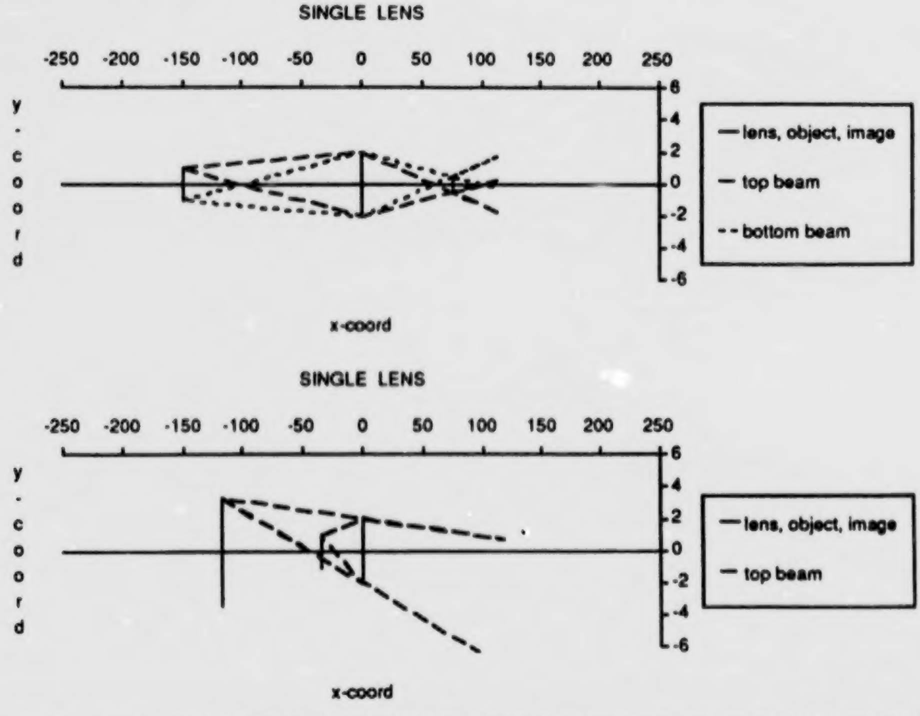
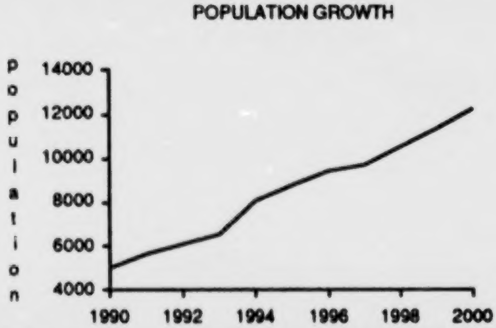


Figure 4. Two sample optical diagrams produced using a spreadsheet that draws one or two beams of light passing through a lens.

POPULATION GROWTH			6th June, 1991
birth rate	death rate	starting	rate of growth
(%)	(%)	population	(as a fraction)
br	dr	start	rate
10	2	5000	=(br-dr)/100
year	increase	population	migration
			into area
X1		Y1	
n	inc	pop	mig
1990		=start	0
	=(lastpop)*rate+mig	=lastpop+inc	250
	=(lastpop)*rate+mig	=lastpop+inc	0
	=(lastpop)*rate+mig	=lastpop+inc	0
	=(lastpop)*rate+mig	=lastpop+inc	1000
	=(lastpop)*rate+mig	=lastpop+inc	0
	=(lastpop)*rate+mig	=lastpop+inc	0
	=(lastpop)*rate+mig	=lastpop+inc	-500
	=(lastpop)*rate+mig	=lastpop+inc	0
	=(lastpop)*rate+mig	=lastpop+inc	0
	=(lastpop)*rate+mig	=lastpop+inc	0



POPULATION GROWTH			6th June, 1991
birth rate	death rate	starting	rate of growth
(%)	(%)	population	(as a fraction)
br	dr	start	rate
10	2	5000	0.08
year	increase	population	migration
			into area
X1		Y1	
n	inc	pop	mig
1990		5000	0
1991	650	5650	250
1992	452	6102	0
1993	488	6590	0
1994	1527	8117	1000
1995	649	8767	0
1996	701	9468	0
1997	257	9726	-500
1998	778	10504	0
1999	840	11344	0
2000	908	12251	0

Figure 5. A simple population growth spreadsheet, showing formulæ(top), graph (centre) and values (the normal view - bottom)

An important feature is the ability to refer to the values of quantities in the row above the current one by preceding their names by the four letters 'last'. This enables step by step calculations (like those for predator-prey interactions and planetary orbits) to be carried out without needing to use cell references. This is illustrated in Fig. 5 which represents a very simple model of population growth in a small town, (some values chosen are unrealistically large in order to make the changes large on the graph for demonstration purposes). Notice how formulae have been copied down to the bottom of the spreadsheet by the 'Initialise formulae' command, but not constants as in the migration column. (The formulae in the first column simply number the rows in the spreadsheet and do not need to be entered by the person writing the spreadsheet.)

Two useful features are provided for spreadsheets based on mathematical models such as the predator-prey one mentioned above. 'Make chosen row new starting row' allows the values in any row to be copied to the first row so that calculations can be continued 'beyond' the bottom of the spreadsheet, for example if one wanted to continue the predator-prey cycles in Fig. 2 for a further 25 years. At the same time constants and formulae can be altered before proceeding, allowing different conditions and models to be used for the continuation. 'Make changes from a chosen row down' is similar in that it allows constants and formulae to be altered part way down a spreadsheet.

REFERENCE NOTES

Note 1. Longman Logotron, Dales Brewery, Gwydir Street, Cambridge CB1 2LJ, England.

Note 2. J. F. Hewitson, The Berrystead Barn, Oundle, Peterborough PE8 4AL.

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'I KNOW ABOUT LISP BUT HOW DO I PUT IT INTO PRACTICE?'

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ABSTRACT

This paper outlines some initial findings of the Learning in Science Project (Teacher Development) on the process of teacher development with respect to implementing the findings of the previous Learning in Science Projects. The findings on course components, the 'pay-offs' for the teachers, reflection and support for the change process are discussed as are the implications of these for further research.

INTRODUCTION

The Learning in Science Project (Teacher Development), which is funded by the New Zealand Ministry of Education has as general aims to develop and investigate teacher development courses that help teachers of science implement the findings of the previous Learning in Science Projects, and that are based on a constructivist view of learning for both teachers and their students. In taking into account the findings of previous Learning in Science Projects, teachers are encouraged to use new teaching approaches and adopt new roles in the classroom, and to clarify and change their implicit theories of how students learn, the nature of knowing and knowledge, the role and function of schools (Claxton & Carr, 1987). A broader statement of aims, the research questions, design and method for 1990 are outlined in Bell, Kirkwood and Pearson (1990).

Two teacher development courses were specifically set up for the research project in 1990: a course for teachers from several intermediate and secondary schools in the local area (called the regionally-based course), and a course for the science staff in a single secondary school (called the school-based course). Both courses were based on the known research findings on teacher development (Bell, Kirkwood & Pearson, 1990) and aimed to help teachers implement the findings of the Learning in Science Projects, related to learning and teaching science. The Interactive Teaching Approach (Biddulph & Osborne, 1984) was used as a vehicle for teachers on the courses to learn about the Learning In Science Project findings and to change the teaching and learning activities in their classrooms. This teaching approach was developed as part of the primary project (Biddulph & Osborne, 1985) and is a constructivist approach, having as its main emphasis, learners finding answers to their own questions. Further details of the courses are given in Bell, Pearson and Kirkwood (1991).

SUMMARY OF THE RESEARCH FINDINGS OF 1990

The findings of the research in 1990 are documented in the papers titled 'Course Components' (Bell, Pearson & Kirkwood, 1991) and 'Changing' (Bell & Pearson, 1991). Reported here is a summary of the factors that helped or hindered the intended teacher development.

'Feeling better about myself as a teacher'

In a survey completed before the courses began, the teachers indicated that a major reason for their volunteering to be involved in the courses and the research project, was to improve their teaching. The courses acknowledged this and focused at the beginning on helping the teachers to trial a new teaching approach in their classrooms. Discussions in the course sessions were largely about the advantages and problems of implementing the Interactive Approach. One factor that helped teachers use the new approach, despite the problems, was that 'they felt better about themselves as teachers':

> I hated school. I did well at school but I was so frustrated...I was bored... I ended up doing teaching because I felt there had to be something better than what I got....I get so frustrated when I see me doing what I got (at school). And so for me, this is some way of helping me become what I think a teacher should be. (16/M2)

[The first number in the transcript code indicates the number identifying the teacher interviewed, the second indicates the number of the interview with that teacher. 'M1, M2' refer to comments made at full day meetings in November, 1990 and in March, 1991.]

The positive aspect of the change was not just the new teaching approach itself but the new roles of the teacher as well (Bell & Pearson, 1991). These new roles for the teacher were considered a pay-off to keep changing despite the difficulties. The role of the teacher as a facilitator of students' learning was seen to involve the teacher in:

- helping students find answers for themselves and 'getting them to think'.
- finding out what students are thinking and helping them clarify, reflect and change their ideas through challenging them
- promoting discussion in the classroom and organising social groups for learning.
- being a co-researcher, giving feedback and providing resources that are motivating and stimulating for students to learn.
- accepting of students ideas and creating a supportive, caring atmosphere for learning.

'Better Learning'

Another factor that was perceived by teachers as helping them to change their teaching in ways consistent with the Learning in Science Project findings, was that the new teaching approach enabled 'better learning' (Bell & Pearson, 1991). During the courses, the teachers tended to talk about what they had done in the classroom in trying out a new teaching approach. Although the talk was often on teaching, many of the teachers also talked about the 'better learning' that was occurring, in terms of the classroom feedback they had received on the new teaching approaches. That 'better learning' was occurring, was perceived by the teachers as a reason to continue to implement the LISP findings, despite the difficulties described in Bell, Pearson and Kirkwood (1991). The 'better learning' was perceived as a pay-off.

> Because it makes us enjoy our job much more. I can justify my being at school and enjoying my vocation if I see kids learning and enjoying learning. (14/M2)

The comments made by the teachers indicated that what they called as 'better learning' included the establishment of better conditions for learning and better learning outcomes. The better learning conditions included:

Increased enjoyment
Teachers commented that there was more enjoyment of science and implied that better learning was occurring:

> Well, there was better learning, there was more enjoyment.... (17/1)

Social co-operation
Increased cooperation was perceived between students with the introduction of the new teaching approach, and was related by teachers to improved learning. In one situation, where experimental equipment had to be shared, the teacher noted:

> The groups really worked together, although they were doing different things to make sure the other group wasn't impeded.... I didn't expect that would happen.... People in such a hurry to get their experiment done, usually became aggressive to someone in their space. (4/5)

Ownership
Teachers saw that when students were able to follow their own research interests, ownership of work was enhanced. A relationship between ownership and improved learning was suggested in the comments of teachers:

> That they were keen!...Another indicator would be that people who didn't normally carry out experiments, ..were actually doing something. Some of the kids who don't normally do anything at science or get very little out of it were actually becoming involved because they were able to choose their own thing, and they saw it as their problem...One of the girls said that she enjoyed this type of approach because she can find out things for herself, the things she wanted to do. (9/2)

Students' confidence
Teachers stated that using the new teaching approach resulted in increased confidence of the students in themselves and implied a link with increased learning:

> I've seen quiet kids respond to this change in emphasis....to the taking responsibility for their own learning...And I can think of one really good example...when asked to defend their theories,...one girl who at that point had hardly said boo all year, stood up ... and said, 'this is what I think and this is why'...It gave her the courage to be able to stand up and say 'I disagree with ninety percent of the class. (13/1)

Motivation

Interactive teaching was also seen as improving student motivation generally and therefore, learning:

> I think the big difference is perhaps the motivation where because they are actually finding out and finding answers for themselves, there is maybe an increase in motivation and that would therefore aid learning. (1/5)

Learning Outcomes

Enjoyment, social co-operation, ownership, confidence and motivation were aspects of the students' learning commented on by the teachers as feedback that the new teaching approach was worth continuing with. They are conditions or prerequisites for learning consistent with the model of learning developed by the Learning in Science Projects (Osborne & Wittrock, 1985). In terms of learning outcomes, many teachers indicated that the strength of the teaching approach was in developing students' learning skills. The skills mentioned included answering and asking more questions, being engaged in debates and conversations about the work in the class and writing down more. These are skills required for conceptual change as researched in the Learning in Science Projects, along with those of investigating and exploring ideas, developing explanations that are sensible and useful and broadening their experiences of science and technology (Osborne & Freyberg, 1985).

> The one topic that I tried it on the fifth form, I know now that they did learn more because I got them to write down what they now know about metals and I was absolutely stunned with what they wrote down there. (17/1)

The teachers also commented on learning outcomes in general:

> I must admit I was really happy with my fifth form. When I just had last years lot that I kept dabbling with and thinking 'well, I will try this and see if I can squeeze this around the exam paper'. And then we get that curly exam paper at the end of the year and my kids did pretty well. With C2 material, we were getting B1's and B2's at the end of the year and I was really happy with what they had achieved. I was actually quite stunned with some of them. They coped better with the strangeness of the paper. (12/M2)

Course Components

The course components were also perceived by the teachers as promoting professional development, with respect to implementing the LISP findings (Bell, Pearson & Kirkwood, 1991) and in summary are:

a) Feeling and experiencing the interactive teaching approach as a student:

At the start of the regionally-based course, the participants became learners of science and technology when the facilitator modelled the Interactive Teaching Approach. The teachers experienced and felt what it would be like for their students when they themselves used the teaching approach in their own classrooms:

> The thing that got me going, initially really put me off, was the fact that the beginning of the course seemed really woolly. You didn't sit down and say to us 'we are going to do this, we are going to do that, and it is just a workshop session we are setting up' and you made us go through the process of - you gave us a starter material which was the iron and told us to get on with it. And you made us go through the process that the students have to go through to be able to accept this approach ...it was great because at the end of it, and when I mentioned about the confidence to try that with students, I said to them 'I know what you are going through, I did exactly the same thing, just give it a bit of time, give it a try and I know it is going to work. And they went through the same process. That was the initial thing that got me on to it. The role play, or whatever, I don't know what you officially term it in the jargon. (17/M1)

b) Knowing about nature of the interactive teaching approach:

Articles on keeping journals, the interactive teaching approach, Learning in Science Projects, science and technology, gender issues and teacher change were given to course members to read in-between sessions. The readings were to provide an input of new ideas and overviews:

> The thing that started me thinking about teaching attitudes was the handouts, the reading matter. And really through that I realised I was not thinking of the education philosophy side of what I was doing. But the reading pointed that out and made me think more why I was doing what I was doing. (11/M1)

c) Doing: using and evaluating the approach with their own students:

Both courses included components of learning about different aspects of the interactive teaching approach, for example, students' existing ideas, students' questions, and students finding answers to their questions. The courses also included opportunities for the teachers to try out and reflect on different aspects of the interactive approach. For some, the opportunity to trial the approach was important:

> I've probably heard enough of the bits and pieces from Learning in Science and that sort of thing, not to have had to worry too much about taking that part on board. It is more the actual teaching method that I needed to look at. So I haven't had too much difficulty, I think, in accepting the concept. It is the actual putting into practice that I think I may have more difficulty with. (1/9)

d) Developing a unit of work based on the interactive teaching approach.

In the school-based course, the staff of the science department negotiated with the facilitator to develop a unit on plants for the school programme. This work was in fact curriculum development. Comments were made about the curriculum development as teacher development:

> Well I think the biggest plus I see is that the whole staff have been involved which means that we have either all taken it on board or we all throw it out. That is something we can discuss anyway but I get the general feeling that the

> staff has pretty much taken the idea on board to a greater or lesser degree. That, of course, is going to make things a heck of a lot easier in terms of planning and making schemes and that sort of thing. If everyone has taken the idea on board we can start writing units in the way that we have done with the plant unit, it is designed for interactive learning. We can work together in resource preparation, whereas if we were in a situation where one, or perhaps two people, on the staff, particularly the bigger staff, have this you may have a lot of difficulty actually actioning the programme. Either because it doesn't fit in with what the scheme is in the school or the actual work they are doing on their own just becomes too much. (1/9)

e) Reflecting on aspects of the approach with respect to teaching and learning, assessment, role of the teacher, curriculum development, the nature of science, gender and equity issues, problems in using the approach, and establishing a supportive classroom atmosphere.

In implementing the Learning in Science project findings, teachers are challenged to change their view of teaching, the role of the teacher, learning, the learner, the nature of knowledge, the nature of science and the science curriculum. Thinking, beliefs and actions are interwoven. Reflection on one's thoughts and beliefs is linked with changing one's actions. Comments were made by members about the role of the courses in aiding reflection with respect to reviewing and evaluating current teaching activities, clarifying ideas, thinking about learners and learning, developing a critical awareness, aspects of science and science education, putting knowledge of teaching and learning into action, and thinking of new teaching activities. An example of a teacher's comment about reflection is:

> Whereas before I was probably pretty cynical about, say, Teachers College and education generally speaking and new modern ideas about how you should teach and things like that, I was probably pretty wary or cynical of those. Which wasn't helped by the other teachers around the place, they would say 'oh yes, all this modern education rubbish'. So I have really changed my tune as far as those go and I can see that there is - well I am certainly able to see, in this particular, probably partly with assessment procedures and inservice courses on assessment and also with the LISP course especially that there is quite a bit that you can do and also the TET business. I found that quite interesting as well. So I began to realise that I would have to make up my own mind about them rather than listen to other people's opinions of them. I went to this with a pretty open mind, quite keen, and so I think that was a good way to go into it and I have gained a lot out of it. (9/2)

f) Supporting each other in the process of change and the need for on-going support was acknowledged:

> I think that is an area where we can share more, particularly if we are looking at developing interactive teaching, then I think that is becoming even more important. We are going to be doing things like that together. And the other thing is if we are developing a new method of teaching then I think we are going to all need support from each other and I can turn around and say 'that didn't work for me, it was a disaster and I really don't want to do it again' and

> somebody will say 'well I went well, I did this and this' and maybe you will see something that they have done that might be different that may change it. (1/5)

This support was felt to be valuable in dealing with the change process, including taking small steps; being in control of the pace of change; coping with the feelings of insecurity; being willing to give it a go, perhaps make mistakes and learn from them; maintaining control in the classroom; getting students to accept the change; having to change within the school system; and keeping a commitment to and opportunity for change.

Summary

Five main factors were perceived by the teachers to facilitate teacher development with respect to implementing the Learning in Science Project findings. One factor was that of the course components of feeling, knowing, doing, developing, reflecting and supporting. Another two factors, 'better learning' and 'feeling better about myself as a teacher', were seen as valuable pay-offs by the teachers in the uncomfortable process of change. These two factors are significant in terms of highlighting the need for teachers to collect classroom information to answer the questions 'Am I teaching in a way consistent with the findings of the Learning in Science Projects?' and 'Are the students learning?'. Two other factors, support and reflection, are important components of the teacher development process and are seen as central in achieving the outcomes of change in classroom practice and ideas on teaching and learning.

RESEARCH PLAN FOR 1991

Reflection, support and indicators of constructivist teaching and learning have been chosen as the foci for the research in 1991, for the following reasons:

* Most existing courses in preservice and inservice teacher education on the Learning in Science Project findings, contain the components of feeling, knowing, doing and developing, although to varying extents. The development and evaluation of such courses (Biddulph, 1990a; Bell & Pearson, 1991) was felt to give sufficient information for the development of course modules and resource material. However, the thinking and course development with respect to promoting reflection and support was felt to be less advanced.

* Reflection may be seen as involving both thinking about our ideas of teaching and learning and thinking about our classroom activities. It also may be seen to involve both thinking and taking action. In terms of the teacher development required to implement the Learning in Science Project findings, reflection can be viewed as a central part of the process of this teacher development. It is also consistent with a constructivist view of learning.

* During the sessions in 1990, the teachers were encouraged to reflect, both publicly (in the sharing sessions and in the interviews with the researcher) and privately (in the journals). It was felt that the kind of reflections required to achieve the desired teacher development often occurred in the interviews, which were not a part of the course but part of the data collection. The quality of reflections that occurred in the interviews needed to be encouraged as part of the course itself.

- The public reflections in the sharing sessions, tended to be describing, recalling, or recounting what the teachers had done in their classrooms, and the problems and successes with the new teaching strategies. It is hoped that with further opportunities, time and support, the teachers would be able to reflect in ways to promote the teacher development (with respect to ideas and practice) required to implement the previous Learning in Science Project findings. This includes reflection as critical analysis and reflection as critical inquiry.

Reflection as critical analysis involves thinking about practice in the light of current educational ideas, concerns and issues at both the school and system level. For example, reflection could involve thinking about new ways of assessment and reporting when using the Interactive Teaching Approach. It may also involve thinking about ethical and moral concerns, for example, gender and equity. Reflection as critical inquiry involves systematic investigation and intervention, and in this sense is similar to action-research with the cycle of collection of classroom data, thinking about the data and suggesting changes to classroom activities. A teacher who is able to reflect in these ways is more likely to change her or his beliefs and practices to implement Learning in Science Project findings. While most of the teachers were reflective to start with, (Bell & Pearson, 1991) further opportunities and support appear to be required if the teachers are to continue developing their skills of reflection, in terms of critical analysis and inquiry.

- The data (Bell & Pearson, 1991) indicate that the support, confidence and trust in the groups had developed to enable public reflection to occur. More detailed data on the kind of support required by teachers to reflect in terms of critical analysis and inquiry and by teachers undergoing change would be helpful.

- Teachers require feedback as to whether their new teaching activities are consistent with the Learning in Science Project findings, or as one teacher asked 'How do I know if I am a LISP teacher?'. This question may be answered from the research findings but the answer is from an academic viewpoint. There is little to answer the question from a practitioner's viewpoint and in the professional language of teachers.

- The teachers looked for feedback from their students as to whether the new teaching activities were improving learning. The indicators attended to by the teachers, tended to be conditions for learning, rather than learning outcomes. More research is required to describe indicators of conceptual change in the classroom.

Acknowledgements

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THE TREATMENT OF SCIENCE DISCIPLINE KNOWLEDGE IN PRIMARY TEACHER EDUCATION

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ABSTRACT

Whilst there is general agreement that primary teachers have a rather limited understanding of science, as Symington and Mackay (Note 1) have shown there is no universally accepted view amongst teacher educators in Victoria about the steps that need to be taken to improve their subject matter competence in science. This paper addresses the issue by taking a topic which is widely included in primary science programs, namely floating and sinking, and asking what knowledge primary teachers should have to enable them to handle the topic in a primary classroom in a way consistent with constructivist ideas. The paper will also address the issue of how that knowledge could be assessed.

RESEARCH INTO CHILDREN'S IDEAS ABOUT FLOATING AND SINKING

Biddulph and Osborne (1984) have conducted and published research into children's ideas about floating and sinking which has provided valuable insights into pedagogical issues associated with introducing these concepts at primary school level. They developed a procedure, utilising a set of pictures representing instances (Figure 1), which facilitates exploration of children's ideas. Biddulph and Osborne asked students to examine each of the instances and say whether, in the way they thought about floating, the object portrayed was floating. This procedure, and responses to it, provide a vehicle for reflection on the way science operates and how this should be taken into account when dealing with primary teacher education students.

REFLECTIONS ON THE NATURE OF SCIENCE

The framework for the reflection on this issue will be provided by five questions:

- Does nature contain a definition of floating which can be uncovered through appropriate experiences?
- How does science deal with an idea such as floating?
- Is there a single explanation for a phenomenon such as floating?
- Can science always provide an answer to a question?
- When a "better" explanation is suggested do scientists readily accept it?

Question 1: Does nature contain a definition of floating which can be uncovered through appropriate experiences?

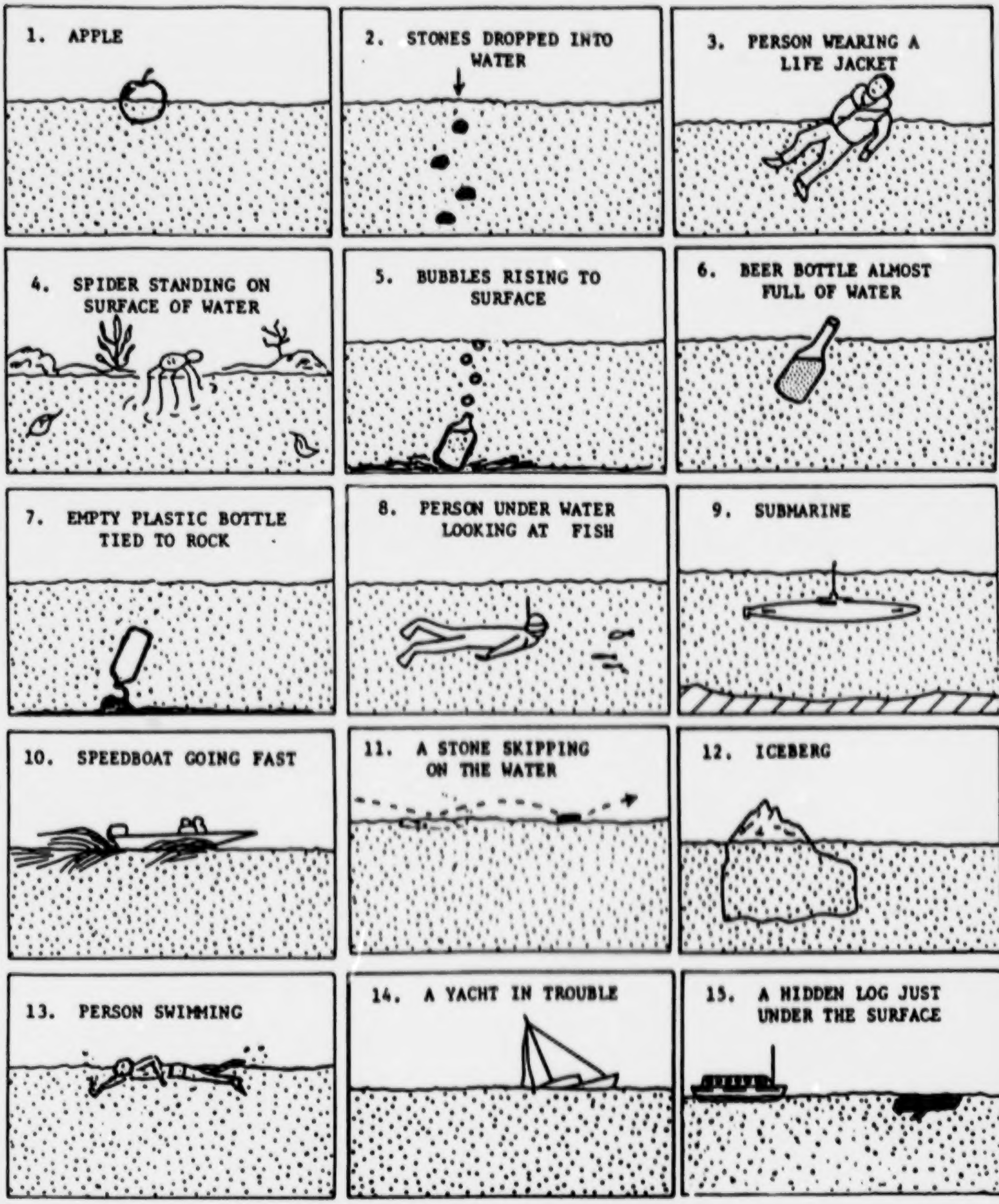
1. APPLE
2. STONES DROPPED INTO WATER
3. PERSON WEARING A LIFE JACKET
4. SPIDER STANDING ON SURFACE OF WATER
5. BUBBLES RISING TO SURFACE
6. BEER BOTTLE ALMOST FULL OF WATER
7. EMPTY PLASTIC BOTTLE TIED TO ROCK
8. PERSON UNDER WATER LOOKING AT FISH
9. SUBMARINE
10. SPEEDBOAT GOING FAST
11. A STONE SKIPPING ON THE WATER
12. ICEBERG
13. PERSON SWIMMING
14. A YACHT IN TROUBLE
15. A HIDDEN LOG JUST UNDER THE SURFACE

Fig. 1: Drawings used to explore individuals' concept of floating.
Source: Biddulph and Osborne (1984).

The implied view of much primary science writing in texts and teacher guides is that a word such as floating has a meaning which exists in the natural world. This meaning is seen to be independent of people, unambiguous, and apparent to the trained and careful observer. Through a process of exploration of their world learners are therefore expected to unearth this true meaning of the word, provided that a teacher guides the process with skill.

The reality is that the word 'floating' does not have an obvious and exact meaning. The understanding of the word which we have constructed from the rich world of our experience is challenged severely when we think carefully about the instances Figure 1). The first example, the apple, may seem obvious and uncomplicated. Surely the apple is floating. Yet if you discuss even this apparently straightforward example with young people some of them will say that the apple is partly floating and partly sinking (which makes sense if your idea of floating is to be above the water and of sinking is to be below the water). The second example might also be thought to be a clear case of sinking, but if the illustration showed one of the stones partly above the surface then the logic of this view would be that some of the stones are sinking but that one is floating.

Consider now the person under the water looking at fish. Is the person floating? If our concept of floating is for something to be above the surface of the water, then the answer is no. But we may bring to this decision other experiences. What if we know that an apple when pushed under water will bob up again when we release it? Then we may decide that floaters can be submerged temporarily, but that they remain floaters. How would this affect our response to the survey question about the underwater swimmer? We know that divers can swim back to the surface, unless something goes wrong (and the person illustrated does not look distressed). By this argument perhaps the person is floating. There is another view of floating which involves the common experience of feeling supported by the water. From this viewpoint the diver is floating, even although submerged. The same considerations apply to the submarine.

Further complexities arise when we turn to the yacht in trouble. In our normal use of language the yacht is sinking but in the illustration it is still floating, if only just! The responses to the instances depend on the construction of meaning for the words, and these meanings come from our prior experiences. In thinking about the instances some interesting ambiguities and puzzling issues to do with meanings for the words have arisen.

The person swimming may set off interesting associations with our own experiences. For some people water is a dangerous environment, raising fears of drowning. To them this illustration may show a person who is going to drown if he/she stops swimming, because he/she cannot float.

Other responses may arise from a personal experience of comfort in the water, knowing that when you cease swimming you can float. Each association could lead to a different response. This picture has introduced a puzzling new dimension, that of movement. We are likely to hold a static view of floating and sinking, which means that movement is a confusing distraction. The same problem applies to the stone skipping along on top of the water. We know that the stone would sink if it stops moving. Does that mean that it is floating? The same difficulties apply to the speeding boat!

If complications seem to be piling up endlessly then the point that we wish to make can now be stated clearly. The idea of floating does not exist sharply defined in nature. We obviously need to make decisions about what the word can be taken to mean, that is we need to construct a meaning for it. This is just what scientists have done. They have constructed their concept of floating and sinking by building up a lot of experiences, and then trying to make better sense of their observations. In the process they have invented theories: at times have had to change these theories and therefore the meanings of the words involved.

Question 2: How does science deal with an idea such as floating ?

Consideration of the instances if Figure 1 gives some clues to the answer to this question. Development of a construct of floating is hindered by the complexity of the rich world of experience. Scientists, for very good reasons, aim to reduce this richly complicated world of experience to a more manageable, tidied-up one. For science to 'work' concepts need to be in sharp focus. In the case of floating and sinking the scientists' construct first seeks to make these two possibilities mutually exclusive (something is either floating or sinking, and ambiguities such as partly floating and partly sinking, floating now but about to sink are avoided). How does this work? Consider some examples.

The iceberg is viewed by science as floating. Although many people will tell you that part of it is sinking (the part below the water) and the rest is floating, this is too complex for science: the total system is defined as an instance of floating. By reducing the complexity of the real situation simpler and tidier statements can be made. The instance of a person in a life jacket provides a further illustration. We might think that the person needs the life jacket to survive so that in a way the person is sinking and the life jacket provides support so that the sinking person can float! Again by treating the system as a whole a simpler, more reduced view of the world offers a clear response. So the first strategy is to treat systems as a whole.

The next decision about floating is to shift the focus from the surface of the water. The new construct considers something to be floating if it is supported by the water (even if it is under the water). The yacht in trouble is therefore considered to be floating since it is still supported by the water.

This example raises a further aspect of the way that meanings for words are constructed in science. The situation is treated as it is at the moment, regardless of what may happen next or what may have happened before. Science often takes this view of the world, disregarding the past history of an event and the possible future. This provides a sharper focus, even though information from our prior knowledge is now ignored. Of course in everyday language the yacht is sinking, but the scientists' construct is that at the moment it is floating. It is valuable to think about how this construction of meaning does not always remove some difficulties.

Consider now the empty plastic bottle tied to a rock. The bottle is described by science as floating although many people would describe it as sinking or sunk since it is beneath the water. Is the scientists' response based on the understanding that if the bottle is released it will float to the surface? This is not the case. The scientist is not using knowledge of what might happen in the future. The decision is based on seeing the bottle as being supported by the water (experiencing an upthrust) and therefore floating. Notice that this decision is affected by the change to the concept of floating from 'being at the surface' to 'being supported by the water'.

This reduction to a simpler, more amenable situation is typical of the way that science works. Focussing on the moment and using the concept of support provides a sharper analysis than being above or below a surface. The idea constructed is more powerful. In attempting to make sense of the world science tidies it up, discarding as unnecessarily complicated a number of the attributes of the real world. By this process science has been developed as an interrelated set of constructs about the world, in which carefully defined ideas work together to inform us about much of our experience of the physical world. When scientists decide to confer onto a word a particular, more exact, definition this is an act of construction from the world of experience significant to scientists.

This reduction of the world to manageable aspects should be understood for what it is. Rather than science being thought of as a 'given' feature of the world around us the learner needs to appreciate that science has been constructed by people as a way of making better sense of the world.

This has obvious implications for primary science teaching and learning. If the language of science develops by taking decisions about what would make better sense of the world then teaching approaches could well model this procedure. Much current practice in primary science teaching is modelled on the idea that science is a body of knowledge which exists independently of people and which can be transmitted as indisputable facts. Teaching approaches which assist students of primary science to construct new ideas from their prior understandings, and acknowledge that science is a human construct would provide a more accurate picture of science.

The implication of this for primary teacher education is clear. We would want the student teachers to appreciate that:

* words used in science have changed their meanings with time as scientists have constructed more powerful ideas;
* the language of science inevitably ignores some of the complexity of the rich world of our experience;
* science often has meanings for words which differ from the use of the same words in our familiar world.

Our next focus explores the reduced world of science from a different perspective by asking another question.

Question 3: Is there a single explanation for a phenomenon such as floating?

A common view of science is that there is a single, scientifically acceptable explanation for any phenomenon such as those represented in Figure 1. Many current teaching practices reinforce this idea and student teachers are often concerned that they don't know the "correct " explanation. To say that the apple floats because it is held up by the water is not as detailed an explanation as one invoking Archimedes' Principle but it is appropriate none the less. The reality is that there are many levels of explanation of any of the phenomena represented in Figure 1 which are in accord with the scientists' view.

A scientist is unlikely to disagree with any of the following explanations of why the apple floats:

- it is held up by the water
- the upthrust of the water is equal to the weight of the apple
- the weight of water displaced is equal to the weight of the apple
- the apple's density is less than the density of the water
- the difference in water pressure below and above the apple results in a net upward force equal to the weight of the apple.

The level of explanation that scientists use at any time depends upon the purpose of the explanation, the background of the person for whom the explanation is being provided and the scientist's own background. It is quite inappropriate therefore that science education should give learners the impression that there is a single correct explanation of any natural phenomenon.

The consequences for primary teacher education are that we would want the teachers to:

- understand that there is no single acceptable explanation for a phenomenon;
- be willing to accept that children in the same class may have different ways of explaining phenomena all of which may be valid;
- be able to provide multiple explanations of a phenomenon.

Question 4: Can science always provide an answer to a question?

There are at least two instances in Figure 1 which test the scientific view of floating and sinking to the limit. The spider standing on the surface of the water and the stone skipping on the water show a water surface and objects associated with it, yet we have real difficulty in answering the question 'Is the object floating?' and so does the scientist. Some scientists would say that the spider is floating because it is supported by the water. Others would say that the phenomenon involved here is surface tension and that the spider is not floating but rather supported by a 'skin' on the top of the water. We can support a needle on a water surface by carefully lowering it onto the surface, but this needle will sink if the surface is disturbed or some detergent is added to the water. The concept of floating held by most scientists requires that water is displaced, but in the case of the spider this has not happened.

The stone skipping on the water is a tricky one since the movement of the stone is vital to it remaining on top of the surface. When its speed drops sufficiently the stone sinks. Science cannot answer the question 'Is the object floating?' in the spirit in which it was asked, even though it looks like a perfectly reasonable one. (There are similar problems with the speedboat, though in this case the boat may well float if it stops moving). The scientific idea of floating and sinking is embarrassed when objects are in motion because the idea then becomes too complex for a straightforward analysis.

The implications of this for primary science are clear. Young learners are very likely to ask questions which do not fit tidily into the constructs of science even though they look to be simple ones. The apparent simplicity of the language often conceals a very difficult problem. A teacher who understands that science does not have all the answers may feel more comfortable about helping a student to explore the world than the teacher who feels threatened by the challenging questions that students will sometimes ask. It should not be considered unprofessional for a teacher to acknowledge that some questions are unanswerable at the level of knowledge of science of the learner.

The last question we should look at as we consider the instances about floating and sinking at the beginning of this paper comes to the heart of the construction of language and ideas in science. We need to explore the process of change in the constructed meanings of words and ideas.

Question 5: When a "better" explanation is suggested do scientists readily accept it?

If science is not a set of truths which exists independently of people, then in the construction of this structured complex of ideas there will often need to be changes made to ideas which have seemed to explain the world of experience. We can argue that this process of changing prior ideas is the core activity of education. The issue of acceptance or rejection of a new idea is therefore an important one for this discussion of language in science. We now know that learners often retain their prior meanings for words rather than taking on new meanings and we also know that this situation is often not apparent to the teacher. If your idea of floating was based on an object being above the water surface then introduction of the 'better' idea that floating involves support by the water will have caused problems. You would need to have explored the new idea and found it to be more helpful and to offer better explanations before you would feel comfortable with it.

Scientists have frequently had to face this difficulty. Although a popular image of scientists is that they quickly accept new discoveries the history of many ideas in science shows that many scientists have continued to disagree with developments in their field for very long times (one commentator on the history of ideas has remarked that new theories in science are finally accepted when the last opponent dies of old age!). When an idea has become part of the way that you think about the world changing that idea will mean overcoming barriers which can be very difficult to break down.

The important point for our discussion here is that although the language of science may appear to be exact there are likely to be many different constructions for words in a classroom. The process of changing these meanings requires more than statements which outline the new meaning, perhaps followed by some exercises. Learners need time to consider their prior meanings, to explore new ideas, and to construct new meanings. The false view of science which holds that scientists are rapidly converted to new ideas has resulted in classroom approaches to science which too often assume that changing ideas is an easy procedure.

The most important feature of an approach to science classes which addresses the difficulty of changing ideas is conversation. Science lessons which continually seek learners' ideas, which help to clarify them, and which provide an open and unthreatening environment for changing these ideas through conversation are classes in which learning in science can be improved.

The false idea that science is exact and that therefore the language of science is unproblematic can be argued to have trapped science teaching into an approach which regards teaching as the transmission of knowledge and learning as the absorption of this knowledge. This approach does not value conversation.

IMPLICATIONS FOR PRIMARY TEACHER EDUCATION

In response to concerns about the lack of confidence of primary teachers in science the Discipline Review of Teacher Education in Mathematics and Science in Australia has recommended that all students preparing to be primary teachers should have the equivalent of one unit of science discipline knowledge (including physical science) which is explicit and assessed. The purpose of this paper has been to establish the approach which it is hoped that such a unit would take. "Science discipline knowledge" should be taken to include the nature of science itself. Further the analysis of floating and sinking suggests that such an understanding can be derived through a program in which the student teachers explore concepts and processes related to primary school curricula. Such an approach seems more appropriate to the interests and the needs of those preparing to be primary teachers.

The understandings which students can be expected to develop from such a program can be explicitly stated, as has been illustrated throughout this paper. Further, since they can be so expressed they can be assessed. It is to be hoped that responses to the recommendations of the Discipline Review will reflect the ideas presented in this paper. This would imply that students will enrol in programs which are not hamstrung by the traditional view of science discipline knowledge.

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TOWARDS TEACHING SCIENCE FOR SOCIAL RESPONSIBILITY: AN EXAMINATION OF FLAWS IN SCIENCE, TECHNOLOGY AND SOCIETY.

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ABSTRACT

In this paper we continue our search for a socially responsible science education by an examination of the trends in the Science, Technology and Society movement. These trends reflect differing ideological perspectives and result in courses which serve different ends. We identify two major flaws in the movement that inhibits the realization of a schooling in science dedicated to democracy. We propose skills necessary for citizens to participate in debate over issues surrounding the impact of science and technology on society and a teaching stategy to help develop them.

INTRODUCTION

In the past two decades there has been increasingly widespread concern over environmental damage and the deleterious effects of much of current technology on the one hand and need for a technologically literate workforce on the other. This has been expressed in schools, and particularly in curriculum development, in the movement called STS (Science, Technology & Society). We emphasize the word movement here, as it has, we believe, influenced much science teaching and curriculum development, whether it is labelled STS or not. While this movement has generated a large literature and a number of special courses in schools, there has been regrettably little recognition of its two major failings. One is that in spite of its wide range and lack of precise definition, major aspects of social responsibility are neglected. The other is that in the materials we have examined the approach has tended to continue the 'rhetoric of conclusions' (Schwab, 1963, pp 39-40) which has been one of the major failings of traditional science courses. Such courses must fail to empower future citizens, though this is often expressed as one of their aims. Here we shall briefly survey the STS movement to bring out these flaws and then propose alternatives. Curriculum materials examined for the purposes of this paper are listed in Note 1.

THE STS MOVEMENT

Many of the ideas informing STS can be traced back into the Britain of the nineteen thirties, and perhaps beyond that (Aikenhead, 1990, citing Hurd). Courses teaching STS began in the universities after World War II (Spiegel-Rösing & de Solla Price, 1977), but there is little evidence of it before the early 1980s in secondary schools. At the 1979 International Symposium on World Trends in Science Education, held at Halifax, Canada, there appeared to be little interest in it (McFadden, 1980). However in 1980 Ziman published his proposals for STS and discussed science for the specialist and the non-specialist and as the decade advanced calls for STS courses appeared more and more frequently. Writers such as Dorothy Nelkin (1982), P. James Gaskell (1982) and Judith and Tony Hargreaves (1983) suggested ways of developing STS and reviewed the emergence of STS in schools in the UK. The extraordinary range of interpretations of STS

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can be appreciated by an examination of the proceedings of the Bangalore Conference, held in 1985 (Lewis, 1987). These interpretations stretch from vocational training that serves industrial and technogical needs at one end of the spectrum to ecological preservation at the other. Certainly, many important social issues are introduced but the force of social criticism is all too often blunted.

The vocational training emphasis is found in a number of the items in Education, Industry and Technology, the third volume of Bangalore Conference materials (Lewis, 1987, vol. 3). The introduction specifically mentions 'the needs of industry' and the importance for development of 'the supply of technicians' rather than the professional scientists and engineers normally considered (Lewis, pp 3, xviii & xvii). A Queensland Department of Education discussion paper juxtaposed more enlightened rationales for S & T studies with another expression of the economic imperative, saying 'any failure to maintain a flow of these innovators and technicians would have detrimental effects upon our agricultural production, communication network, national defence and general industrial capacity' (McAllister, 1985). A particularly disturbing formulation regarding the curriculum and the 'world of work' is to be found in the recently circulated draft of the National Statement on Science for Australian Schools (DEET, 1991). This speaks of '(w)orkers (who] need to be adaptable to and comfortable in an environment of change as new scientific discoveries are made and new technologies developed. Science education can help to prepare students for this.' (p.7). This is to assume that current industrial practice is one with which human beings can be comfortable by adapting to it. Alas, all too often this is not the case and what an STS course should be doing is exploring why and what might be done about it. In another volume of the Bangalore Conference materials a different agenda can be recognised when it speaks of 'a science and technology education which promotes sustainable development', or of 'the evolution of non-harmful and adapted "intermediate" technology' (Lewis, pp. 8, 9 & 86). Here, rightly, it is the technology, not the workers, which must adapt!

Teaching materials, too, reflect the ideology of 'autonomous technology' (Winner, 1978), the need for people to cope with, to be responsive to changes in and to accept the inevitable consequences of technology. The Star Wars' section in Future Science Today, (Brunning & Hely, 1988) is an example of the glorification of technology to the neglect of discussion about the societal structures that give rise to technology and encouragement of students to evaluate evidence. The UNESCO resource entitled Educational Materials Linking Technology Teaching with Science Education: Technology in Life (UNESCO, 1988), has many worthwhile aspects: alternative energy sources using high and low technology, such as photovoltaic cells and windmills. But these are portrayed without giving students the sort of information that would enable them to make judgements. The recently published Structures and Machines (Snape, 1990), part of a series dealing with science and technology at work, is a simplistic celebration of the power of scientific knowledge applied to the general good of people. Finally, Science, Technology and Society (Perin, 1989), a complete junior Australian science course, tends to deal with issues, e.g. acid rain (Book 2, pp. 26-38), as a simplistic two sided issue, rather than considering the weight of evidence for all 'sides'.

At the ecological end of the spectrum of STS materials there is a tendency for the emphasis to move towards the protection of the 'natural' environment without consideration of the human and social (Price & Cross, Note 2) Examples of this are some of the courses of Environmental Studies/Science which have been established in different countries, courses which we regard as part of the STS movement, though they do not employ that acronym. While these may have the objective of 'describ(ing) the effects of human activity on the way environments function' or 'understanding the environmental consequences of the interaction of natural systems and technology' (VCAB, 1990), they often direct attention in quite other directions. The same Victorian example suggests as suitable environments for study 'alpine, aquatic, arid, coastal, riverine or volcanic'.

Aikenhead (1990) has recently tried to categorise STS according to the proportions of 'standard school science' and 'STS content' involved. By STS content he means:

- interactions between science and technology, or between science and society, and any one of the following or combination thereof:
- a technological artifact, process or expertise,
- a societal issue related to science and technology,
- a philosophical, historical or social issue within the scientific community.

As well as not helping to clarify problems of teaching for social responsibility this formulation suffers from the common confusion about the meaning of technology, a confusion which we avoid by directing attention to the nature of the theoretical processes involved (Cross & Price, Note 3). The interesting and useful distinction, we argue, is that between theories to explain and theories (recipes) to make or do something (Price & Cross, Note 4). Furthermore, STS courses seldom reveal the multitude of influences that determine the construction of knowledge. Without this, students are ill-equipped to deal with the social issues that arise. In this regard there is little doubt that science teachers themselves gain little understanding of either the construction of knowledge or the nature of science during their training (Blank et al., 1988) and that this is a major difficulty. To sum-up here, in spite of some more encouraging examples - the PLON materials (1984) for physics in The Netherlands,, the CEPUP materials for chemistry in the USA (Thier, 1991), The Salters' Chemistry Project (1987) and the SATIS (1986) projects in the UK - the problem of whether the movement will provide citizens with the skills and knowledge for understanding and participating in informed discussion about issues is still to be resolved.

TOWARDS TEACHING SCIENCE FOR SOCIAL RESPONSIBILITY

The social responsibility movement today is much broader and deeper than that of the thirties and forties. It has been enriched by the women's movement. Names like Rachel Carson, Ruth Bleier and Barbara McClintock spring immediately to mind, but there are many more. The other major force has been the ecological movement, the 'Greens' of differing persuasions. The thirties generation working in the period of the Great Depression and the clash of Fascism and Communism questioned Society but tended to take Science as they found it. The social responsibility movement today questions both. Writers stress that Science is a human production, constructed by individuals working within the pressures of institutions, influenced by ideologies, interests and values, some conscious and some not. It is not surprising, therefore, if many Science teachers feel unsure how, and even unwilling, to proceed. Yet, as Bernal saw so clearly (in a paper originally given in 1939), the Science teacher 'if he (or she) is to fulfil his responsibilities must understand the complex "social and economic organisation" which forms the context of Science' (Bernal, 1949, p. 143). He went on to make an interesting distinction between impartiality and objectivity, a distinction we would see perhaps more deeply today, arguing that the Science teacher:

> must concern himself with immediate practical social problems. . . To do less would be to admit that science was just a play of words and would inevitably create in the minds of students the idea that it was an ineffective adjunct to life, instead of one of the major agents of social change.' (Bernal, 1949, p. 143)

While the spread of scientific literacy is much greater than when Bernal was writing science teachers still represent a large body of trained people with a significant potential for action. Their potential comes from their relative lack of 'interests' that so often thwarts the possibility of action. Indeed Bernal quite specifically appealed to science teachers to be especially responsible for the 'study and the criticism of the attempts to modify the social and material structure of the community in which he works' (p.137). STS opens a way. If it can strengthen its critical approach towards Society and Science/Technology itself, more Science teachers may support it. There are encouraging signs in curriculum statements of several countries. The UK's National Curriculum signals the need to understand the 'power and the limitations of science in solving. . . problems' (DES, 1989, pp. 75 & 80). The rationale for scientific literacy in the American Association for the Advancement of Science Project 2061: Science for All Americans (1989) states:

> Scientific habits of mind can help people in every walk of life deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty; without the ability to think critically and independently, citizens are easy prey to. . . purveyors of simple solutions to complex problems (p.13).
>
> Technological principles relating to. . . assessing the use of new technologies and their implications for the environment and culture, without an understanding of those principles, people are unlikely to move beyond consideration of their own immediate self-interest (p.13).

Making both Society and Science/Technology problematic will not be difficult, though for some it may be painful. But other questions remain for which the answers are not so clear. But they will need answers if teachers are to be willing to teach and students are to learn a socially responsible approach. These questions include:

> How to make Science problematic without further weakening students' confidence in it?
>
> How to make questions fresh and interesting which the mass media have done to death (shades of 'the convicts' in Australian history here?)?
>
> How do we handle problems involving science which is regarded as beyond students' level of understanding? Or, if STS is only a part of a science course: how do we maintain the sequencing of science theory while handling the science necessary for understanding the STS issue?

> How do we maintain a stress on evaluating evidence in the case of those many important problems involving statistical proofs, often beyond the teacher's critical competence?

WHAT WE ADVOCATE

At the outset it should be understood that our concern is with the great majority of students who will not go on to become scientists or technologists, but will require an understanding of science if they are to play their part in the democratic process. We also see no conflict between secondary school courses in science which make social responsibility-STS their focus and the preparation of students for tertiary schooling. Rather the reverse, they will, in our opinion, be better prepared. In this we take comfort from a number of studies, including those referred to by Aikenhead (1990, p. 27).

Teaching science for social responsibility requires resources and information much of which is available, though not organised in a suitable manner. It also requires attention to certain skills. These are:

- for understanding the arguments;
- for judging the experts;
- for carrying out independent investigations in the literature and in the field;
- a knowledge of and ability to participate in democratic ways of influencing decisions.

At the present time there is an acute shortage of materials in a form which would enable teachers to fulfil these objectives. However, we feel there are certain steps which teachers can take which would help to transform the usually large quantities of materials which do exist, whether popular or too technical, and however biased they may be. These steps are as follows:

- Defining the project: this involves choosing the topic, whether a general topic like radiation or chemical waste, or a more specific topic like genetic variation. Ideally choice will be made with regard to the current situation, the interests of the particular students and what is relevant to their lives. But this will depend on the extent to which social responsibility permeates the syllabus and is tied to external assessment. Where one or both are high choices may be predetermined. But in most cases there will be definitional work to perform, clarifying the major questions and slant of the project. Starting from the general topic of radiation teachers may decide to focus on ionising radiation, or more narrowly, nuclear power generation; or they may choose non-ionising radiations, the effects of magnetic fields, radar and micro-radiation on living things, about which concern is increasingly being expressed (Dalton, 1991).

- Sorting the questions: having selected the project teachers must then brain storm and sort as many questions as possible relating to the chosen project. Particularly important at this stage is to consider which are the key controversial questions. These may be controversial simply in a political sense because of differing interests. Or, and more importantly for science teaching, they may be questions about which there is controversy among scientific experts. It is the latter where science teachers have a particular responsibility and an important job. In such cases it is often difficult for the general public to understand what is happening, yet in the democratic process they may be called on to take sides. Science teaching must be able to provide guidance in such situations, revealing precisely why it is that the experts disagree. Another part of sorting the questions will be distinguishing and relating the scientific from the social (whether ethical, political, economic or whatever) and considering the way in which these are related.

- Handling the arguments: one of the first steps in this stage will be to decide how to handle the essential social questions, whether these lie within the competence of the science teacher or whether they should be dealt with in other school subjects or by other teachers. Secondly, it is important to avoid reducing the arguments to a simplistic 'debate' between two sides, 'for' and 'against'. Rather, it is a question of clarifying the question and examining evidence on all sides of what is usually a many-faceted question. Debate should be encouraged about the nature of evidence required and the weighting to be given to different evidence, and value-free analysis may be useful here (von Winterfeldt, 1986). Teachers must consider how to develop understanding of the general problems of proof and the nature of scientific belief through handing the particular arguments of the project.

A number of other steps are important, but need not be discussed here. Careful consideration must be given to the concepts involved and just which will be taught and how. Particular teaching methods may be chosen for particular projects and resources, both for the teacher and the students, will have to be assembled.

CONCLUSION

In the past two decades the STS movement has made a contribution in bringing into the schools many of the major problems which face humankind (Solomon, 1988). But it is still weak at the classroom level, and by and large has failed to endorse a democratic vision for science education. The lack of critical attention to which we have pointed is a major failing. Society and Science are too often taken as given when it is precisely here that the STS approach can be challenging and genuinely educational. In a world where current technology produces overwork for some and unemployment for many, and where the endless stream of gadgets seems more to provide profitable employment than to solve genuine human need, it is surely time to demand social responsibility. There are, we believe, many risks to the environment and human well being and it is, we believe, the task of the movement to come to grips with these issues.

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GENDER DIFFERENCES WHEN CHOOSING SCHOOL SUBJECTS: PARENTAL PUSH AND CAREER PULL. SOME TENTATIVE HYPOTHESES.

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ABSTRACT

The literature has made us all aware of large gender differences in students' attitudes to science, in enrolment statistics in upper high school and tertiary level science courses, and in different spheres of employment. What have not been looked at in detail are the factors which are influential when students begin to make choices in early high school, choices which may well set them on a particular pathway from which it is difficult to turn.

This preliminary study identifies factors which students in a Year 9 class believed were influential on the limited subject choices they had been able to make in Years 8 and 9, and the factors they believed would be most influential on choices to be made later in the school. In addition the students' views of science, of the separate sciences, and of their anticipated career patterns were sought.

Several interesting findings were made which, if validated in further work, could lead to strategies which would support other approaches designed to reduce gender imbalances related to science.

INTRODUCTION

While much is known about gender differences in students' attitudes to science, and in enrolment statistics at upper high school and tertiary levels (for example, de Laeter, Malone & Dekkers, 1989), very little research has focussed directly on the factors which are influential when a choice of school subjects is being made, especially in early high school, despite the fact that these choices probably create a 'flow-on' effect into the later years.

Pitt (1973) reviewed the literature on a range of factors which might be influential, and concluded that early choices are liable to be made following a cursory reflection on perceived small differences between options. However initial small differences tended to become magnified by the nature of the subjects chosen. For instance, while some students had slight initial preferences for syllabus-bound subjects, and others preferred syllabus-free subjects, this eventually led to distinct science and humanities cultures in the English 6th form.

Woods (1979) examined how choices were made by Year 9 students in an English school. He suggested that two major groups of factors influenced their decisions; firstly an affective component (liking/disliking), and secondly a utilitarian component (career/ability). He noted that girls tended to be more influenced than boys by the liking component, while boys had a stronger career orientation, and were less swayed by likes and dislikes. Parental influence ranged from compulsion to nil, and showed a heavy utilitarian focus, especially amongst parents of top stream students. Teachers' involvement was low, and tended to be aimed at ensuring that the students entering their classes would be in some way 'acceptable' academically or otherwise.

In an Australian study, Sleet and Stern (1980) invited Year 11 students to select from a list of twelve options no more than three which they believed had influences their choice of particular science subjects. For those who had chosen one of the two courses which involved the study of chemistry and physics, the most important factors were both career orientated - 'choice of career', and 'keeping one's options open'. This was true for both the girls and the boys in these two courses. For those taking the biology course, 'interest' was listed as the single most important factor. Significantly, 'interest' was rated more highly by girls than by boys in every course, as was the relatively minor factor 'advice from the family'.

Since these reports, little research seems to have been focussed on these matters. But in view of the recognised importance of the eventual imbalance between girls and boys enrolling for certain subjects, including the different science subjects, this appears as a major omission. In a small way this study begins to fill this gap, by focussing on the factors affecting the choices made by 21 students (13 girls, 8 boys) at the beginning of Year 9, and their view of how these same factors will influence future choices.

METHOD

The study was conducted in June with one Year 9 mixed ability class in a metropolitan Catholic High School. While the initial intention was to select about 30 students randomly from across the four Year 9 classes, the school found this impossible to organise, and this lack of randomness served as a constraint on the design of the study. The students had chosen one language from Italian, French and Japanese at the beginning of Year 8, and in Year 9 had chosen firstly whether to continue their language study or take a course in Asian Studies, and secondly from a range of electives including a one year elective in Music, and semester electives in Applied Science, Drama, Extended Art/Design, Extended Mathematics, Typing, and Physical Education Skills Development.

For several reasons, the major one being the opportunity to personalise questioning, an open-ended interview schedule (Burns, 1990) was used to identify students' views about the factors which had affected their decisions in the immediate past (at the beginning of Years 8 and 9), and also those which they would expect to influence decisions at the end of the year (for Year 10).

The interview was designed with sufficient time allowed to follow up an individual's response when it was idiosyncratic, unclear, or perceived to contradict an answer given earlier in the interview. The following factors, which were culled from the literature, and from the researchers' own experience, served as focus points for each interview:

- the influence of mother, father, peer group, teacher(s)
- perceived difficulty of the subject
- the amount of homework expected
- the teacher's reputation
- interest in the subject
- career expectations

Because a major emphasis of the study was to identify factors which might lead to the selection or rejection of science subjects, a second set of questions addressed the following.

- interest in year 9 science lessons
- memories of the first semester's science course
- comments on the most/least interesting sections of the course
- suggestions about the ways science lessons might be improved.
- understanding of the probable content of senior biology, chemistry, geology and physics courses.
- how Year 9 science compared in difficulty and interest with English, mathematics and social studies.
- perceptions of the relevance of science to their future careers
- knowledge of, and attitudes towards, senior science courses
- feelings about the relative involvement of boys and girls in senior science courses.
- attitudes to the place of science in our community.

RESULTS

Influences of choice

Influence of parents

Parents were reported as being more influential on year 8 and 9 decisions by more girls than boys (10 girls (77%) and 3 boys (38%): this pattern accords with Sleet and Stern (1980). Parental influence ranged from rigid compulsion to 'talking over'. All the boys had talked with both their fathers and mothers, but only 4 girls had done so, with 6 receiving advice from only their mothers. Their expectations were that when making choices at Year 10 level, parents would be rather more involved (12 girls: 6 boys), but again, while most suggested both parents would be involved, 3 girls expected to consult with their mothers only. The general pattern seemed to involve parents in solving dilemmas, giving approval, and making helpful suggestions for the long term (for instance several students had been given advice to select Japanese because of its expected long term value), and only one case of virtual compulsion (to take Italian) was reported. Students seemed to seek, and value, parental advice more than that of teachers or friends.

Influence of peer group.

8 girls and 4 boys stated that peers had had some influence on Year 8 and 9 choices, but fewer (7 and 2) expected them to influence Year 10 choices. Rather they believed that career interests and personal relevance would be more important.

Influence of teachers.

Few students had consulted with teachers before making their choices (3 girls and 2 boys), and 6 girls and 1 boy expected they would do so for Year 10 choices. 7 girls and 3 boys considered that the teacher's reputation had been somewhat influential, but the expectation was that it would be less so for Year 10 choices (3 girls and 1 boy). One view seemed to be that a student may simply have to put up with bad teaching once a definite path had been chosen. Current teachers of a subject appeared to exert an indirect influence by affecting whether or not students like a particular subject.

Perceived difficulty of a subject/amount of homework.

7 girls and 3 boys believed that perceived subject difficulty had dissuaded them from enrolling in certain subjects in Years 8 and 9, and 6 girls and 4 boys thought it might in Year 10. However some believed that they might have to put up with a difficult subject to reach their goals. Japanese was seen to be difficult, but useful, and so presented something of a dilemma for students making choices. The anticipated homework load affected few students: they were generally inclined to accept its necessity as part of future school life.

Interest in the subject

Interest in the subject permeated many of the interviews and as an influential factor it seemed to rate below career and parental influence, but above friends, teachers, subject difficulty or the amount of homework. However the concept took on different meanings for different students, therefore providing an area which should be more deeply researched in the future.

Career considerations.

Almost all of the girls (12), and the majority of the boys (5) were able to state their career orientation (Table 1)

Career interests had a strong influence on subject choice even in Years 8 and 9 (8 girls and 6 boys), and it was expected to be much higher in Year 10 (12 girls and 7 boys).

Attitudes to science

Students had just completed their Year 9 first semester course in science, and had all been taught by the same teacher. 10 girls and 4 boys expressed a liking for what they had done, whereas the rest were negative. 7 girls had enjoyed the environment topic, but only 1 boy had, with one believing that "you sort of feel like you are hammered about the environment by everyone." 1 girl had enjoyed 'chemistry' and 3 'rocks', whereas 4 boys and 1 boy had enjoyed these same topics. 'Rocks' had been found "boring" by 4 girls and 5 boys. Overall the girls had been more interested in this particular science course.

TABLE 1.
EXPRESSED CAREER ORIENTATION OF YEAR 9 STUDENTS

Girls	Boys
fashion designer	lawyer
journalist	computing career
'perhaps a secretary'	electronic engineer
P.E. teacher or tourism	pilot
secretary	computing technician
career in tourism	
'something to do with art'	
veterinarian	
air hostess or teacher	
'something to do with animals'	
a business career	
gardener.	

Both girls and boys believed that the course would be more interesting with the addition of more practicals and activity. Girls also believed that more discussions and projects would make it more enjoyable.

Perceived relative difficulty and interest.

Students were asked to compare science with mathematics, English and social studies with respect to both difficulty and interest. Table 2 presents a summary of responses.

TABLE 2
PERCEIVED DIFFICULTY AND INTEREST OF SUBJECTS
BY YEAR 9 STUDENTS.

Difficulty/interest level	Girls	Boys
Difficulty Increasing	Maths/Science	English
	English	Maths/Science
	Social Studies	Social Studies
Interest Increasing	Social Studies/	Maths
	English	English
	Maths	Science
	Science	Social Studies

For girls science was seen as both more difficult and less interesting than English and social studies, even though, it will be remembered, some aspects of the first semester science course had been found quite interesting. Boys saw science only slightly more positively and, while they saw English as being more difficult, they were more interested in it. A similar low interest, steadily declining throughout school years was reported by Yager and Penick (1986) who somewhat flippantly suggested that if we want students to consistently report their enjoyment of science, we would stop teaching it in third grade.

A particular factor which several students associated with the perceived difficulty of science was the need to obtain the correct answer, whereas in English and social studies some marks at least could be obtained for giving an opinion. Yager and Penick (1986) also commented on the exactness of science and the fact that few students make the highest grades.

Students' knowledge of the branches of science.

Students were asked to say what is meant when the terms biology, chemistry, etc. are used. Boys seemed to have rather more knowledge about each area, though overall understanding was not high, and it was particularly low for physics (Table 3)

TABLE 3
PERCENTAGE OF YEAR 9 STUDENTS WITH AN UNDERSTANDING OF THE SCIENTIFIC DISCIPLINES.

	Chemistry	Physics	Biology	Geology
Girls (n=13)	9 69%	1 8%	11 85%	6 46%
Boys (n=8)	7 88%	2 25%	8 100%	4 50%

It has to be said that while some of these percentages are relatively high, attribution of some understanding was given relatively easily. For instance, 57% of the girls and 50% of the boys described biology as "something to do with dissecting animals", even though they had neither conducted nor seen a dissection in their science classes. It was interesting to note that plants were never mentioned.

Predicted Year 11 first choice

When asked which science subject would be their first choice in Year 11 (in this school students must select at least one science from biology, chemistry, physics and general science), major differences between girls and boys were again observed (Table 4). In order that these selections were somewhat informed, students were given a brief description of each area about which they were unclear before the question was asked.

TABLE 4.
YEAR 9 STUDENTS' ANTICIPATED FIRST CHOICE FOR A YEAR 11 SCIENCE COURSE.

	Chemistry	Physics	Biology	General Science
Girls (n=13)	2 15%	1 8%	7 54%	3 23%
Boys (n-8)	2 25%	4 50%	1 13%	1 13%

Evident in Table 4 are the anticipated gender differences. Of particular interest are the boys' responses to physics. As seen in Table 3 only 25% could initially say anything about what it is, but on being given the information, 50% said they would make it their first choice. The girls tended to favour biology as their first choice and believed it would be interesting, though their ideas about it were rather hazy.

Perceived difficulty and relevance of senior science.

11 girls (85%) and 4 boys (50%) believed that senior science courses would be difficult, some having been led to that view by other students. Students were not yet thinking of these courses in terms of gaining high marks in public assessments as probably tends to be the case later.

All the boys, but only 6 (46%) of the girls, believed that the study of senior science would be of some relevance to them. For most of the boys this was of career relevance, but relevance for the girls was to life in general, not to careers. More than half the girls thought senior science would have no relevance of any sort: the junior science course, together with a compulsory Year 10 health unit, would be quite sufficient.

Attitudes to boys and girls entering careers and studying science.

Virtually all the girls and boys believed that there should be equal opportunity as far as the choice of careers is concerned, and believed that males and females would be equally capable in any career. However, both girls and boys believed that the sexes would have different interests, particularly when it came to careers, and hence would choose different school subjects, including different science subjects. There was a strong attitude reflecting "women can, but don't want to" (Dillon, 1986).

Attitudes to science in the community.

While students were well aware of the negative side to science, they chose to emphasise the positive: the contribution science is making to the solution of environmental problems, and the outcomes of medical research, were cited often. The positive nature of their responses is in harmony with Schibeci's (1986) study.

DISCUSSION

The way in which individual students make their subject choices, and the factors which ultimately affect subject enrolment patterns, career interests, and eventual career patterns are highly complex. Much has already been written elsewhere about various aspects of gender imbalances, including those related to science, however little work has previously focussed on the factors which are taken into account when subject choices are being made. While this study is only a small one, and its results require replication and extension, possibly through use of a questionnaire based on its findings, it does shed some light on how students make their choices. From it a few tentative suggestions will be made about strategies to ensure that the process of making choices is made in a more information rich climate.

Before going further, it is important to identify the problem being addressed, and to set it within a broader perspective. It would seem to be totally inappropriate to mount an argument, or to suggest strategies, aimed solely at encouraging more girls into the areas of physical science and technology or, on the other hand, to encourage more boys to take up nursing or typing, or other currently female dominated careers. Students should be in a position to make their choices, from the early years of high school onward, in a climate which makes them fully aware of where those choices might lead, and of the implications involved when some subjects are dropped.

The interview data from this study shows the Year 8 and 9 choices had been taken seriously, but had often been made when the information available was limited, and similar choices might have been made for different reasons (for instance, one girl had selected typing because of her intention to become a secretary, but a boy selected it to help with his computing).

A major feature was the difference in the ways in which the girls and boys saw their future, and the place of science in it. While more girls were able to state their career interests than boys, the differences in interests of the two groups were marked by major stereotyping. While the girls seemed to have gone beyond the very traditional stereotypes, and a business/commercial career was quite a popular one, few of the careers mentioned require scientific or technical qualifications. Even the girl who wished to become a vet had seen no relationship between this and a need to continue to study science. For the boys the career interests were more scientific/technical.

Not surprisingly, this gender difference was matched by the overall attitudes to science. It is of concern to note that the interest in science expressed by both girls and boys was below other commonly taken subjects, however the boys seemed to be kept on a physical science track by a strong utilitarian, job related, interest. 6 of the 8 (75%) boys anticipated that either chemistry or physics would be their first choice for Year 11 science, despite their knowledge of these subjects being relatively low: only 22% of girls selected one of these. This selection by boys matches data from other studies (for instance, Harvey & Stables, 1986; Dawson, Note 1) showing that many boys think biology (or biology and chemistry) is more interesting but select chemistry and physics because they are seen as more useful for careers: what Woods (1979) has named 'instrumental compliance' (see also Sleet & Stern, 1980). While it was not evident in the data from this study, it is very likely that, in contrast with the long term career orientation of boys, girls consider future home commitments as one component of long term plans. Compatibility of these plans with any future career is of importance (Birke et al. 1980). In this regard a career in science does not rate highly amongst the possibilities.

In a sense, making these subject choices, within the framework of both current interests and long term plans, becomes an attempt to solve an ill-structured problem, and, as Chi, Glaser and Fan (1988) point out, there is no single correct answer to such a problem. Instead the solution favoured depends on how the problem is presented and perceived. In the matter of subject choice, many factors can be influential, and individuals tend to weight them differently but the trends observed amongst this small group of students will, it appears, in due course lead to traditional enrolment patterns in senior school science, and in eventual career choices.

What are the possibilities for changing these patterns if a school wishes to actively intervene? Douglass (1985) has suggested that the decision to pursue science is probably made during childhood, and, if interests can be used to judge the situation, it is evident that even in middle to upper primary school, boys' and girls' views of science can be quite different (e.g. Dawson & Bennett, 1981). So is a high school in a position to do anything?

Evidence from high school intervention studies in several countries has demonstrated that some change is possible, primarily through strategies which utilised gender inclusive teaching methods, and attempt to change the image of science itself, and of science based careers (see Kahle, 1985; Stage et al., 1987); this approach needs to be continued. But are there additional possibilities?

Two features of the current data bear on this matter. Firstly, while Year 8 and 9 choices had been taken seriously, there was evidence that for some students at least this was done in an information poor climate. Secondly, the girls in the study were more dependent on advice from others, especially their mothers, than were the boys. Similar results to this have been reported by both Kahle (1985) and Woods (1979).

Using this information, together with the knowledge that interests in science and in future career patterns tend to be developed relatively early in life, two additional tactics are proposed. Firstly, high school career programs should be introduced much earlier. Currently, in South Australia at least, programs are very variable. They are usually offered in Years 10 and 11, and may include work experience, careers evenings, use of computerised data bases and so on. In the new South Australian Certificate of Education pattern, a work related aspect is a compulsory component of all Stage 1 (Year 11) courses. However, in the context of this study, much of this seems to be too late. Early programs are needed, not primarily to focus on particular jobs, but to introduce all students to broad areas of possible employment, what each offers, and what requirements have to be met. This early information, given at lower secondary level, could be more influential than the usual Year 10 and 11 programs in making information available at a critical time.

A second tactic would be to attempt to ensure that the individuals with whom girls are likely to consult are themselves well informed. This would include school personnel and parents, especially mothers. Remick and Miller (1978) suggested that counsellors can easily become a negative factor in girls' choice of science subjects, due to lack of knowledge of career structures in technical areas. The influence of many mothers on girls is likely to be similar. School programs, which actively involve parents, especially mothers with their daughters, could emphasise the gender differences in educational and career patterns, and provide an information base for a range of careers, including technical ones, while ensuring that examples of women pursuing both career and family interests are made available.

Interestingly, while this paper was being finalised, a 'Career Expo for Young Women' was held in Adelaide. This was organised by the Department of Employment, Education and Training for Year 9 and 10 girls. Its aim was to "assist the girls in making vital career and subject choices necessary for the achievement of their personal ambitions", and based on the knowledge that 'womens' employment is primarily restricted to a narrow range of occupational groups" (DEET, 1991). This demonstrates a movement in at least some of the directions suggested above.

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EVALUATION OF A TECHNOLOGY UNIT IN A GIRLS' PRIMARY SCHOOL

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ABSTRACT

Rapid advances in technology are changing the structure of the workforce. There are elite highly-paid hi-tech occupations and low status poorly-paid jobs. Women are unfortunately more likely to be found in the latter category. To allow them to qualify and compete for the higher-status positions, girls need to participate in the physical sciences and in technology studies. However, they are rarely attracted to them in secondary school, possibly because they are already alienated from them by the time they leave primary school.

This paper reports some of the outcomes of a curriculum unit taught in two primary school classes in an independent school for girls. The unit was cross-curricular, involving technology, science and other fields of knowledge; it made extensive use of LEGO Technic materials. The evaluation of the unit, based on observations, a teacher journal and pupil questionnaires, focussed upon the issue of whether it assisted the girls to feel happier about working with unfamiliar technology and feel more capable of doing so. Implications for teaching technology are also discussed.

INTRODUCTION

Most societies are experiencing rapid technological change, resulting in changing lifestyles and restructuring of the workforce. This will advantage some workers, but may bewilder many others who will start to lose their chance to compete in the workplace. Populations will probably divide into the technologically wealthy and the technologically poverty-stricken, and women are unfortunately more likely to be included in the latter group.

The workforce of the 1980's has many well-educated professional women, but many others have been relegated to dead-end or part-time jobs which offer lower incomes and fewer prospects of promotion. Management has remained closed to them (Connell, Ashenden, Kessler & Dowsett, 1982). Women tend to be clustered in community service, in lower-level jobs in the finance, property and business sectors or in leisure industry occupations. Many jobs have little female participation, e.g. mining, where women comprise 9.7% of workers in the industry, electricity, gas and water (11.4%) and construction (12.3%) (Note 1). Without education in technology for girls, this situation is unlikely to change.

Technology and technology education

Technology is a vast field of human endeavour which encompasses

> the goods and services which people make and provide to meet human needs and the knowledge, organisational systems and processes used to develop and deliver

> those goods and services. Technology meets human needs through a marriage of thought and action, a combination called technological capability. (Gardner, 1990, p. 125).

Technology education is important if individuals are to understand the rapid technological development in their world and if they are to compete in the workforce to gain economic independence. A highly-skilled workforce is also necessary if Australia is to compete successfully in world markets to repay its massive debts (Note 2).

Technology education includes the learning of skills in the technical arts, the making of links with knowledge drawn from various fields (science, mathematics, computing...) and the consideration of the broader context e.g. how technology affects us as a society, its benefits and disadvantages. Technology makes extensive use of scientific knowledge and also generates scientific knowledge; although obviously linked, science and technology are also distinct (Gardner, 1990).

The Technology Studies Framework P-10, (Victorian Ministry of Education, 1988, p. 12) considers technological knowledge in three categories:

- knowledge that has "special significance for application and production - materials, energy, engineering, systems";
- knowledge "associated with the technological process -- concept, design, manufacture, evaluation"; and
- knowledge from other areas of the curriculum.

Girls in technology education

Subject choices made by many girls seriously limit their chances of employment and the range of tertiary study open to them, which in turn narrows their career options. They show under-participation and under-achievement in the mathematics/physical science combination, making them ill-equipped for entry to tertiary courses in computer science (Commonwealth Schools Commission, 1984). Similarly, girls are not being attracted to the technical arts (Black, Harrison, Hill & Murray, 1988). Fowler (1987) believes some of the reasons for this under-participation include societal gender expectations; sexual harassment; girls' unfamiliarity with technology; teacher attitudes; courses and teaching methods; and lack of female role models. Girls do not have the same chance to develop some of the understanding of systems and machines that boys learn through tinkering with mechanical toys. By the time they have left primary school, most girls have already developed the attitude that technology is not for them. Girls may lack the confidence to participate in technology studies, inhibiting their chance of eventually competing in the workplace against men for high status, highly-paid, high-tech occupations.

THE PRESENT STUDY

In the hope that girls could be helped to feel happier about working with unfamiliar technology and more capable of doing so, a cross-curricular technology unit was designed by the first author for students in Years Four and Five at Toorak College, an independent school for girls. A detailed study of the effects of this unit (Note 3) forms the basis of this paper.

The students

The students came from middle to upper class families. There were 25 Year Five students, belonging to the class taught by the first author. The Year Four class (27 students) belonged to another teacher, who willingly allowed the first author access to her class.

The Year Four Unit

The video Transport and Society was used to introduce the unit; it emphasises the value of machines in our society. The central resource used in the unit was the LEGO Technic 1 kit. The kit contains twenty cards, each containing comprehensive pictorial instructions for building various systems and machines. The kit includes all the parts needed to build them. The LEGO kit was complemented by a book, Work and Machines (Simmons, 1985), which contains worksheets for developing ideas about simple machines, levers, pulleys and friction. The computer software, The Factory, simulates a machine assembly line and makes use of geometric concepts.

The girls learned how to build systems from components and tested them to see if they would work. They learned to recognise how a system worked by tracing what happens from the source of energy through to the final output. Relevant science concepts were introduced when the appropriate stage of technology was reached. For example, after the children had built a wheelbarrow, the principles of levers were studied. Mathematical concepts, language work, art/craft work, music and drama were included to make the learning experience a cross-curricular one.

The children worked in groups through the LEGO cards and the appropriate worksheets from Work and Machines. The unit was taught in weekly lessons; each group of children could use the LEGO before school and at lunchtime if they wished. The unit was divided into sections. The first section developed ideas of stability, movable and rigid structures. In the second section, the purpose was for children to recognise levers and examine a variety of ways in which they are used. The third section was concerned with sliding and rolling. The stated purpose is "investigating friction and resistance, and explaining ways of overcoming friction when moving loads" (Note 4, p. 16). Slides, rollers, conveyor belts and cables were included. The models offered many opportunities to initiate discussions of factory technology and how large machines are used in the course of construction. The inclined plane was discussed here together with the principle that the longer the board (or equivalent) the less the steepness, with less effort therefore required.

The purpose of the fourth section was to study "the notion of gearing and how it makes work easier in a variety of machines" (Note 4, p. 18). Learning the rules applying to using gears or pulleys to transmit movement is an important objective in this section. The fifth section, on lifting, aimed to examine "pulleys (both singly and in the block and tackle) and their application, together with gears and levers, in machines that lift heavy loads" (Note 4, p. 26). The sixth section was about steering. One of the models was a two- wheeled barrow which can also be changed so the wheels are fixed to the same axle. One interesting model in this section represented the steering in a motor car, where the front wheels are mounted on a split axle and turn through differing angles.

Curriculum areas associated with the unit

Many other curriculum areas were linked to the unit. Some of the science concepts have already been noted. It is worth emphasising that the overall goal here is not to teach a clearly identifiable unit on science, but to allow relevant scientific experiences and ideas to emerge through interactions with the technology. Mathematical concepts included the measurement of angles through the computer software on The Factory; this also contributed to the students' computer education. Social studies were introduced through videos and discussions about how machines have affected the development of society; this helped to place technology in its historical context.

Drama work assisted the children to express their ideas in forms such as mime, an activity which they greatly enjoy. Miming machines, copying actions of specific components such as gears, added a new dimension to the unit. In line with the thematic approach often adopted in primary schools, there were opportunities for language work, such as poetry and creative writing, e.g. inventing a story about how a machine caused chaos. Such activities allow children to use their new vocabulary and experiences as a basis for their written work.

The Year Five Unit

For the Year Five unit, the major resources were LEGO Technic 2 and LEGO Technic Buggy 1, used in conjunction with the LEGO Technic Manual Controller. Some of the more advanced girls used the computer-driven TC LOGO. Some of the girls linked model-making with art and craft, by designing motor-driven ballerinas, complete with backdrop scenery! All other resources and cross-curricular work were similar to Year Four, except that The Factory was replaced by other computer software, Machines and Force; this explores the concepts of the lever, inclined plane, pulley wheel and axle.

The Year Five unit was taught as a whole block, instead of once a week for an hour. The girls were allowed to move at their own pace. Once they had all passed a point, such as levers, on their machine building, the whole class lesson on the group of worksheets was completed.

One session was spent cross-age tutoring the Year Fours to explain their machines, which included cranes, front-end loaders, cars and trucks. There was also a useful session when the Year Fours played with and then dismantled the machines built by the older girls.

EVALUATION

Evaluation issues

The two focus questions were:

- Will learning about technology in a cross-curricular technology unit assist girls to feel happier about working with unfamiliar technology; and
- Will they feel more capable of doing so?

The evaluation study utilised both quantitative and qualitative methods. The former comprised a pre- and post-unit questionnaire, designed to provide data on the students' feelings of happiness with which they viewed the possibility of working in eighteen different occupations and their feelings of capability in these occupations. The response options for the former were very happy, happy, don't mind, unhappy and very unhappy; students were asked to tick the appropriate smiley face on a five-point scale. Students' feelings of capability were assessed on a three-point scale (yes, unsure or no); they were asked to circle the word which best answered whether they thought they could do the job. Included among the 18 items was a six-item Heavy Machinery scale comprising the occupations of tow truck driver, tractor driver, crane driver, cement truck driver, bulldozer operator and front-end-loader operator; this scale is the focus of this paper.

In addition to these quantitative data, observations of the classes were made continually by the first author; a journal was kept while teaching the units.

RESULTS AND DISCUSSION

Perceived capability

The pre- and post-unit responses to the six Heavy Machinery items are compared in Table 1. The total number of responses was 162 (27 respondents x 6 items) at Year Four, and 150 (25 x 6) at Year Five. The data show a marked swing to 'yes' answers to the question: 'Are you capable of doing this job?' at both year levels. (Incidentally, although this superficially resembles a chi-square problem, that statistic is quite inappropriate here, since the 162, or 150, responses are not statistically independent.)

Happiness

Ratings of happiness at working with heavy machinery are shown, separately for each year level, in Table 2.

TABLE 1

PERCEIVED CAPABILITY TO WORK WITH HEAVY MACHINERY

	Year 4			Year 5		
	Yes	Unsure	No	Yes	Unsure	No
Pre unit	48	64	50	35	60	55
Post unit	104	38	20	132	12	6
Change	+56	-26	-30	+97	-48	-49

TABLE 2

DEGREE OF HAPPINESS TO WORK WITH HEAVY MACHINERY.

	Year 4					Year 5				
	+ +	+	0	-	--	+ +	+	0	-	--
Pre unit	2	21	67	43	29	0	1	31	64	54
Post unit	6	27	69	36	24	1	19	75	39	16
Change	+4	+6	+2	-7	-5	+1	+18	+44	-25	-38

+ + = Very happy + = Happy 0 = Don't mind - = Unhappy -- = Very Unhappy

At Year Four, the data show a slight but obviously insignificant shift from the 'unhappy' to the 'happy' category. In Year Five, in contrast, there is a marked swing, mainly from 'unhappy' and 'very unhappy' to the 'don't mind' category.

Comments expressed by the girls during a class discussion just before the unit was completed provide supportive evidence of an increase in confidence and capability:

> Pleased with myself because I actually built something and made it work.
>
> I found it easier than I thought it would be.
>
> You feel more capable of working them, now you've seen how they work.
>
> It's fun!
>
> I learnt how to control my nerves...when I build something and it falls apart, I don't give up. I just keep going.
>
> When you put things together, you learn how they work, so when things fall apart, it's interesting to find out what's wrong, why they don't work.
>
> I just learnt how to read pictures to build things.

When asked if the unit had affected the way they felt about working with big machines, like trucks and cranes, the comments included:

> I didn't think I'd have anything to do with machines, but now I wouldn't mind.
>
> I'd like engineering or to become an architect.
>
> I'd like to work with machines.
>
> I'd work with machines some of the time. (There was a general nod of agreement to this comment).
>
> Feel better now, because it always seemed a man's job. The machines looked big and complicated. I wouldn't have wanted to work on them, um ... in case they broke down. Now that doesn't worry me.
>
> I feel I can handle them now, they don't seem too big and frightening to me now.

When asked if there were any other comments, the following answers were volunteered:

> I enjoyed inventing.
>
> Yeah, and we improved on each other's inventions.
>
> Yes, we shared ideas and inventions and had a really good time playing with them.

Asked if there was anything they disliked about the unit, some students said they wanted more equipment, more advanced equipment and more spare parts. There were no comments reflecting dislike for the activities.

The Year Five unit was particularly successful; the girls appeared to enjoy the activities and spent a great deal of time inventing their own machines. Although each student did not complete every model in the series, students discussed each other's machines and inspected them to see how they worked. The atmosphere was one of excitement and enthusiasm.

In general, there were improvements in the girls' feelings of capability in tackling heavy-machinery occupations (and also in some of the other occupations in the questionnaire). This is important, because they may now be less likely to reject careers which involve technology usually associated with "men's" work. There was also an obvious improvement in the degree of happiness to work in technological occupations, but only for the Year Five girls.

Possible reasons for differences between Year groups

Several explanations may be offered for the better outcomes at Year Five. First, the Year Five girls were taught by their own classroom teacher, so both the teacher and students understood what was expected from each other from the start of the unit. Second, the Year Fives had more time to relax and enjoy their machines. About 60 hours were spent on it in class, apart from the time spent on building machines before school and at lunchtime. The Year Fours had only 26 hours and did not have the same amount of equipment for all girls to have unlimited time with "hands-on" experience. However, it is not simply a difference in the relative amounts of time. The Year Five unit was taught as a block, while the Year Fours had brief weekly lessons.

A third possibility is that there are developmental differences, with the older girls being more receptive to learning about technology. Fourth, the Year Five girls built powered machines, while the younger group built only hand-operated models. The Year Four girls enjoyed playing and investigating the powered machines the Year Fives had made and shared with them, so perhaps when they build their own powered machines, there will be improvements in their happiness ratings. Finally, the smaller shift in the happiness ratings at Year Four may reflect the fact that their pre-unit ratings were more favourable to start with: most responses on the pre-test were already in the Don't mind/Happy categories, while at Year Five, most were originally in the Unhappy/Very Unhappy categories.

IMPLICATIONS FOR TEACHING TECHNOLOGY

The study supports the value of the cross-curriculum approach, to allow the concepts being learned to be explored and explained in many different ways. Strategies include story writing and drama, factual writing about what they are doing, and opportunities to study associated ideas from social science, science, computer technology, language and mathematics. Art and craft are also important for exploring materials and design. This area may also be extended to make moving characters for plays or poems, thus linking art/craft with literature as well as technology. These strategies were used in this study and it helped the girls to draw together, in many ways, the practical knowledge they were gaining. Verbalising about what they were doing orally and in written form consolidated their concrete learning. Furthermore, using the knowledge they had gained to design something utilising art and craft methods helped them to recognise that technological knowledge is valuable for various activities, not just for building machines.

Observations made during the study point to the value of small-group work for reinforcing knowledge, solving problems and allowing students to build upon each others' ideas. Some who felt insecure at the beginning of the unit were given valuable help and support from a peer and they eventually experienced success, which led to increased confidence in their ability.

The experience with the Year Fives suggests that technology should be taught in a large block of time, rather than as a once-a-week specialist "subject" on a time-table. It seems reasonable to argue that the Year Fives became "totally immersed" in technology, a teaching procedure which allows potentially favourable learning experiences to have a greater impact. Working in this way also allows children the opportunity to stay with a task until they have completed it, rather than having to dismantle and pack away equipment in accordance with the arbitrary dictates of a timetable. Block time also allows for time to "play" with the machines. "Play" is in inverted commas because sometimes, in the course of play, the machine stops working properly. The study showed several cases of valuable learning occurring as students explored how to rectify the problem. This can lead to consolidation of mechanical knowledge and skills, and a feeling of being in control of the situation.

The curriculum unit would almost certainly not have been introduced without the presence of a teacher with a specific interest in initiating technology studies. Spreading the idea to other classrooms requires planning and working in a co-operative fashion between the initiating teacher and other classroom teachers because of the latters' better knowledge of the class.

The most important implication of this study is that it has shown that primary school girls can be taught to build model systems and machines. Discussion with the girls revealed that they had felt afraid of using heavy machinery, but now felt they could work in an occupation which involved it. This could possibly lead to wider career choices for them. If girls are not given such opportunities early in their schooling, they are likely to avoid post-primary technology studies because they perceive that technology is alien to them.

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STORIES TELL BUT WORDS CONCEAL - ASPECTS OF HISTORIOGRAPHICAL RESEARCH

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ABSTRACT

The author has been invited to write a history of the Science Teachers Association of Victoria which celebrates its 50th year in 1993. He explores the idea of a useful history which addresses present-future concerns which persist, and contrasts this with an authentic history of the past committed to understanding a period. What can be enlisted to help us respond to our current dilemmas are the emblematic characters amongst the agents of change to whom we can speak, and there are the artefacts and their meaning in contemporary discussions abstracted from the record of their past which is not restricted to their contingent circumstances or to their authentic utterances.There remains the question of how to write the history. Is it to be essentially a narrative constructed from stories or a history of ideas based on words of the ongoing conversation amongst those engaged in it, about science teaching?

A Useful History of Science Education?

There are advocates of historical research who argue that curriculum histories of the past uncover the buried potentialities of the present. They argue that while the histories of textbook reforms are contemporary, the traditions of the disciplinary subject matter and of schooling are older and reflect traditions that have been laid down over many years, even centuries. William Reid (1985, p.290) for instance, in arguing against the management view, claimed that "the proposition, that plans will be accepted if they can be shown to lead to desirable ends was tested and found wanting", in the sixties and seventies. Kliebard (1975) has criticised the limited intellectual framework of curriculum workers who were pre-occupied with the production-line model and utilitarian criteria. From Reid's and Kliebard's perspectives, history is to the curriculum workers the problem rather than the solution and the curriculum they are inventing is seen as a design to ameliorate the current state of affairs which has been produced by mistaken plans of the past.

These historians of the curriculum also criticise the institutional histories which they say have assisted in the projection of a "managerial" view of curricular change. Educational history, they claim, has been seen as the study of successful policy making and planning through centralised agencies that have emphasised in their Whig history the evolution of current practices and the extinction of other exotic species in the ascent to the present.

Drawing upon distinctions that Schwab (1978) popularised, Reid argues for practical or deliberate, rather than technical curriculum work, and would value the assistance that history or past action can give curriculum workers. Histories, he says, firstly, can deal with change of actions and not merely plans. Action is something for which someone is accountable and to give an account is to place the action within both the context of the person's individual history and that of the setting in which it is played out. Rather than in the assessment of the technical merit of the plans or purpose, Reid sees recognised value in historical assessment of the context in which action is proposed. From this perspective we should assess, for instance, the success and failure of the general science movement in Australia in the human context of the professionalization of science and democratic forces in the war years rather than against the inadequacy of textbook schemes in the superbureaucracy of University Schools Boards.

Secondly, he says historical research can be concerned with modification of the particular and not merely general purposes. He would prefer an historical understanding drawn from analysis of the particularities of individual's motivations and actions in an attempt to draw guidance from universal explanations, such as Piaget's stages of cognitive development. The notions of story and the exercise of virtue which Reid (1987) calls from accounts of reform are drawn from a complex analysis of moral philosophy and the modern condition. In our actions and practice, as well as in our fictions, we are defining something for which we are accountable.

Thirdly, he says historical accounts can reveal limitations, due to implicit assumptions, in theories of change, and hence lend themselves to pragmatic evaluation. He would argue that Piaget's stage theory or theories of the function of the reader of science texts for instance, which are held by curriculum workers to aid practical action, should be understood pragmatically rather than by their internal logic.

Reid (1985) argues for history as in "understanding" over social science as in "explanation". He is interested in stories rather than words. However the problem in research in science education is not only that it has often lacked the historical insight Reid admires, but that it has also lacked that technical and institutional analysis which he does not. It has attended neither to the stories or the words of science educators. It seems to me that the history of the potential in the present of science education must shed light on the quality of what Westbury (1983) calls "invention" by attending to the detail in the practical reasoning. In the service of invention, research should be engaged, as Hamilton has put it, in an analysis of the available material and ideological resources. In general I have found that whilst stories tell of peoples' commitments words conceal thought as much as they reveal it; at best they may signal the presence of submerged thought. The history of science cannot be simply the recovery of "experience", stressing the active making of Australian culture through human agency. What has also to be sought is an analysis of the text both oral and written for both experience and structuring rules, assumptions and commitments. The analysis should lead to an understanding and explanation of the conditions of both stability and change.

In discussions with authors, I rejected the assumption that the writing in science text-books and syllabi, for example, can be seen either as independent of the author, in some way controlled by the language or conventions of science texts, or the product of the author's personality, whim or fancy. Rather, I assumed that there is a zone of freedom between or convention language and style which is neither strictly historical, technical nor irredeemably personal. It was assumed that there is an aspect of their analyses which is concerned with the moral form of the text which reflects the power of association or the influence of networks. The "unity of Science" is here far more a unity of comparable dedication than a unity of common total understanding.

Historiographical studies can help us understand the transformation of ideology and function in important texts which have been used in science teaching. They can present a more satisfyingly complex view of the writing or utterances of those who invented them. The focus can be on the writers' consideration of the social use which they have chosen for their text and their commitment to this choice. However, the authors have argued that they cannot generally put their writing at the service of a social group or ethical end as is implied by some social scientists: that is to say, they do not decide matters of consumption. In this account the writer's choice, which amounts to a way of conceiving science education, is a matter of conscience as much as efficacy. The history is therefore not concerned to attribute bad faith or moral delinquency to the authors who have guided, they say serviced, science teaching. Neither has it presented reality in a prejudged form. Much of the technical writing could not be lastingly revolutionary: each scheme appeared to degenerate to dogma and pedantry, although many of the authors quoted were proposing radical change in their time. The committed writing quoted will illustrate an ambiguous reality. On one hand, the statements unquestionably arose from a confrontation of the writers with the classroom realities of their time; on the other, writers were often referred back by a sort of tragic reversal to the conventions of the classroom text which they saw to be the practical instrument of creation of classroom reality.

Towards a Contemporary Historiography

My interest is in the practical past-present of science education in Australia rather than its historical past. This distinction needs to be developed and the historiographical essays of Michael Oakeshott (1983) and Laurence Stenhouse (1978) have been of assistance in this regard. In short, Oakeshott argues that the practical past is composed of artefacts and utterances which are alleged to have survived from the past and been recognised in terms of their worth to us in our current engagements. This he contrasted with an historical past, composed of passages related to historical events, which have not survived into the present and that are assembled as answers to historical questions about the "authentic" past. Stenhouse argued for sustained field work leading to the creation of "case records" that could be made available for scrutiny, verification and cumulation. By such a strategy, he sought to overcome weaknesses in case study work which he felt often paid too little attention to detail, and exhibited premature theoretical closure.

The form and content of old General Science texts, or attempts in the Web of Life to teach about the scientific imagination or ASEP's prescriptions for a commonsense science, may each be recognised by their design which to the instructed may indicate the makers' names, an event, or a place (Fawns, 1988). Without any great sense of oddity we recognise another text, syllabus change, or examination reform as belonging to this past of schemes which have survived. Many ideas, expressions, conventions, common places, have survived, embedded in the vernacular of ordinary discourse amongst those engaged in it, about what science education for all is, and what it ought to be. Oakeshott's metaphor for culture is a conversation to which history and utility are only contributing voices. Cultural objects, he argued, can provide us with words of the conversation but our individual interpretation and sense of them is crucial.

By contrast, in historical enquiry an artefact or utterance is a puzzling survival from the past. Historians commit themselves to their period of study. The practical past of science education in respect of what is studied, its contents, procedures and meanings is different from but related to, historic questions about official pronouncements about the curriculum or the administrative machinery delivering it. There are however other historical enquiries into the present artefacts and utterances of science education which are more likely to be confused with the purposes of this study and which also need to be distinguished from it. An historian may connect the surviving records of the origins of General Science for instance to a somewhat obscure reference in the preface to a current text, and in a critical enquiry seek its authentic utterance. The historian may thereby seek to convey to us whatever advice or wisdom those utterances may contain or the true vision of the General Science movement. However, the proposition that such advice comes to us from a past composed of historically authenticated performances which have survived can hardly be accepted.

What is capable of being enlisted to help us respond to our current dilemmas is something quite different. There are emblematic characters amongst the agents of change - the school teachers and university professors to whom we can speak. Then there are the artefacts - textual materials, examination syllabi and papers - and their meaning in current reasoning which are in contemporary discussion abstracted from the record of their past in an understanding of them which is not restricted to their contingent circumstances, or to their authentic utterances. Stereotyped individuals, materials and situations are all implicated in the persistent problem of settling the place of school science in general education. This is the past of science education with which historical enquiry begins. My study is not a collection of heroic exploits but of schemes. My interest in the ASEP Guidelines Conference (Fawns, 1989, 1990) is not evoked in a spirit of a quest for the original ASEP but ASEP is recalled as symbolic propositions and values, not as an historically understood past which may be understood from them, but for their present usefulness in describing the prospects for reform today. The different social functions sought or ascribed to the textbooks; the different roles of the reader of the text; and the different claims to represent the nature of science are three themes which connect the studies of the practical past to the contemporary context.

Edgar Jenkins (1978) and David Layton (1973) have sought an authentic history of ideas, such as "nature study" and "a science of common things". The whole history of science education as an important aspect is seen to be encompassed in each idea and to posit certain fundamental historical trajectories. Waring (1979), on the other hand, tendered processes of social change in an instance of curricula innovation. Like Jenkins and Layton, however, she described the social changes and the achievements of pressure groups not as entities but as the products of the efforts of men and women with distinct and differing attitudes who perceive and select from the milieu not only what is the case but what they take to be the case. Waring characterised the processes of social change in the Nuffield Science Projects as a cultural context between mobilising and conservative ideologies of the sixties.

Oakeshott, like Waring, argued that the relationship between antecedent historical events and a subsequent event that is recognised as their outcome must be a contingent relationship; that is, it must be reinterpreted in the contemporary context. This relationship can be distinguished from the notion of historical "chance" adopted, for example, by Bronowski (1960), in which selected events from the past are used to describe the evolution of current cultural practices, thereby attempting to derive from history a transcendent rational judgment. The contingent relationship between past and present can also be distinguished from a relationship that is claimed in snapshots from the past of science education to support theory called in to explain general causes, or to appeal to normality.

What then is this so called "past" which hovers over us when we recognise these artefacts and utterances to be objects which have survived somehow to account for the potentiality of the present? Certainly we may acknowledge ourselves to be indebted to the makers and authors of science education, but this may be no different from the debt we owe to a contemporary who provides us with a new text or an example of how we should behave, or a piece of sage advice about how a topic may be better taught. If we ascribe some merit to what has survived in texts or as operating principles, we are not attributing to it a significant location in the past; we are accounting for its present usefulness in terms of its durability. Were we to infer from these surviving utterances and artefacts a past composed of lessons we now believe ourselves to have learned from them, then the inference would be false. In short, this practical so-called surviving "past" is not past at all. My research is to contribute to a conversation about the present-future of science education which is composed of schemata that are recognised by practitioners broadly defined to have survived from a near or distant past and recalled to use, from their resting places in the present, to be understood and valued for what they have to offer in the current practical engagements of science education.

Passages of Change

Oakeshott argues that an assemblage of historical events, which are recognisably different, may be understood as a passage of change because of their inherent continuity. This continuity may be distinguished from some changeless item such as a particular text, or an enduring purpose such as science for all. Continuity can also be seen as other than the normalities or the "laws" of a process of change that are provided from historical or sociological theory. The coherence in my accounts of the three schemes I have investigated - General Science, The Web of Life and ASEP - has been sought in their continuity; that is, in their circumstance rather than in an imported framework. In the historical passage the differences or distinctions between them are noted and discussed to compose yet another subsequent difference. In this way, continuity is recognised as a continuity of practical theory.

It could be argued that such an account of the practical past of science education would admit of no surprises and be devoid of great changes. It could also be argued that this approach would be unable to accommodate or reflect "revolutionary" changes. On the other hand, the idea of a revolutionary new form of text belongs more to the vocabulary of a practical understanding of the past, rather than to that of history which has no place for such a judgment.

A general social history of which education is a part may assume "at any given date the political, the economic and the artistic do not necessarily occupy the same position on their respective curves" (Oakeshott, 1983, p.115). The waxing and waning of such influences on science education must be given precedence in what is primarily an educational study. The investigations are concerned to explicate, through schemata invented to maintain and transform science in schools in different historical circumstances, the practical conversation that is science education. It attends to what the schemata may be alleged to say of interest and instruction to current circumstances. Neither the words (people have used to characterize the task) nor the stories (they tell about their past actions and those of others) can be subordinate to the other.

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STUDENTS' ESTIMATES OF KNOWLEDGE GAINED AS MEASURES OF THE QUALITY OF TEACHER EDUCATION

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ABSTRACT

One set of measures of the quality of courses for the preparation of science teachers stems from the perceptions exit students have of their knowledge with respect to that teaching. The Discipline Review of Teacher Education in Mathematics and Science surveyed these students late in 1988 on three broad types of knowledge -science content knowledge, curriculum knowledge, and pedagogical knowledge. Some of these findings of the Review are described. In addition, the base for developing items to measure these three types of knowledge is discussed in this paper. The variety in the data that emerged is also presented and the consistency of the findings with other measures of quality is described.

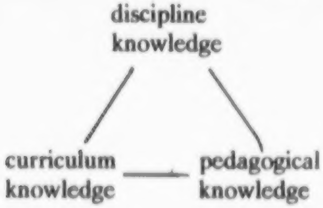
INTRODUCTION

The National Disciplinary Review of Mathematics and Science Teacher Education in 1988 was charged with reporting on the quality of the teacher education courses in the then 52 autonomous Australian institutions offering such programmes. The Review Panel responded to this and its other terms of reference in a three volume report that became available early in 1990 (Speedie *et al*. 1989). Fensham and West (1990) have discussed the complexity of the task such reviews face when charged with the obvious and straightforward request for a quality assessment. They mention, among the sources of data that contributed to the Panel's senses of quality, the responses of exit students (students about to complete their course of teacher education) to questions which asked them to assess certain knowledge they had gained that related to teaching. This paper is concerned with some of the issues that were involved in seeking such student measures.

A conceptual framework for science teacher knowledge

The Review began in July 1988 and the Panel quickly realised that if any systematic data were to be collected from exit students it must be a high priority since these students would become inaccessible during October. It thus needed a conceptual framework that would enable appropriate sets of questions to be devised quickly. The framework it chose to use involved three sorts of knowledge - discipline (or science content) knowledge, curriculum knowledge, and pedagogical knowledge. This framework to a considerable extent encapsulates the view of teacher education the Panel had throughout the Review. That is, it is the framework which its members used to enquire about and to assess what they heard about the actual learning experiences students had as they were prepared for teaching. It was not, of course, the framework the Panel used when it was investigating the factors associated with the provision of such courses. The framework for that purpose was very different and it involved the staff, the resources, the institutional opportunities and constraints, and the schools and school systems with which each course was cooperating. Volume 1 of the Report deals extensively with these aspects of provision, which also have major effects on quality.

The separateness and linearity with which the three sorts of knowledge have been listed above do not do justice to the sense in which they were a framework for the Panel. Figure 1 sets them out in a manner that indicates that the sorts of knowledge were not independent in the eyes of the Panel.



Although each of the sorts of knowledge (the nodes in the Figure) can be described separately and each had its own set of questions in the survey questionnaire, the Panel had sense of interaction between them that requires the connecting links in Figure 1 to be addressed as well.

Fig.1 The framework of knowledge and the interactions between its components in diagrammatic form

The Panel thus saw a science teacher as a person (a) who has acquired, and knows how to acquire a body of scientific knowledge, (b) who understands that a curriculum for science is drawn up from a number of sources including as its major source, the content knowledge of the disciplines of science, and (c) who has acquired a range of pedagogical strategies that relate to the teaching of science as it has been represented in the curriculum.

Some of the sense of linkage between the three sorts of knowledge can now be indicated by the following connecting propositions and examples (*in italics*).

Curriculum - Discipline The bits of disciplinary content knowledge of science that are included in a curriculum are a selection only and are included for certain reasons. The curriculum for any science course is a deliberate set of choices to include and emphasise certain sorts of science disciplinary knowledge at the expense of others. The inclusion of some sorts of disciplinary knowledge in the curriculum has advantages and disadvantages for different groups of learners. *A study of human movement is rarely included in school science despite its relevance, whereas the movement of inert bodies under ideal conditions is extensively studied.*

Disciplinary knowledge of the sciences is often not in the form that it takes in technology and hence for curricula that emphasise science in society. Disciplinary science tends to de-emphasise Australian aspects of science whereas curricula may wish to emphasise them. Disciplinary science is open to gender critique that may be important for curriculum. *What counts as "pure" water in many Australian contexts is quite different from the sense of "pure" water than school science usually develops.*

Curriculum - Pedagogy The real world context of science and technology can be included in pedagogy in a number of different ways. *Excursions, debates, newspaper analyses and practical investigations can lead to the learning of the broader science of these contexts and provide anchorage for learning the narrower science concepts in any curriculum.*

Assessment requirements in the curriculum can reinforce or destroy good pedagogy for learning. *Test items that have only "correct" answer are not conducive to a science course that sets out to encourage real world problem solving.* Pedagogy should be a response to the demands and intentions of the curriculum. A curriculum has many components and aspects and hence there need to be many pedagogical strategies if optimal learning for all is to occur. Groups among the learners will respond differently to parts of the curriculum but pedagogies are available to avoid this leading to differential learning. *Creative writing responses may make an otherwise uninteresting topic an exciting one for some students.*

Discipline - Pedagogy Science uses concepts in special ways that need to be recognised in the teaching of science.

The interrelationship between concepts and processes in science needs to be recognised by pedagogy (and curriculum). Science phenomena, concepts and processes in pedagogy can take on quite different character and relationships in the pedagogical situation from what they have in disciplinary science. *The espistemological status of "chlorine is a green gas" in chemistry as a discipline can be very different from what it is in classrooms where it is never available for observation.* There is a wealth of pedagogical knowledge among teachers that relates to quite discrete and specific phenomena and concepts in science. *The right to left convention for writing organic formula is of no concern in the discipline. It needs care and attention in pedagogy for new learners.* The historical dimension in science has great potential for pedagogy. Pedagogical strategies are needed that can deal with the well established alternative conceptions learners have compared with current scientific orthodoxy. *Co-operative group work and predict (observe) explain (p.o.e) have proved to be useful pedagogies for teachers wishing to take these research findings seriously.*
Unfortunately the clarity of our understanding of these linkages was not great when we had to construct the instruments for the survey so early in the Review. We thus defined the sorts of knowledge almost entirely in terms of the nodes of Figure 1 and these processes are now described.

Discipline Knowledge It was assumed that students wishing to teach in secondary programmes and who have studied science over several years in higher education should acquire some broad understandings of science as well as much specific knowledge of the content areas that are particularly represented in most curricula up to year 12. For early childhood and primary teaching students, only questions about the specific content areas were asked and these in relation to teaching up to year 3 and from year 4 - 6 respectively.

The broad aspects of science are listed in Table 1. They were defined from the profiles of a well prepared science teacher the Panel set up from various sources (existing practices, the literature and research). They are reported in Chapter 3 of Volume 1 as realistic targets for science teacher education. The specific knowledge areas listed in Table 2, were derived from the Panel's knowledge of school science curricula in Australia.

Curriculum Knowledge The same items were used with all respondents but the confidence in them was related to teaching at the specific levels for which particular respondents had been prepared . They were derived from contemporary curriculum theory and concerns and from the Australian interest in teachers' role in the development of curriculum within broad state outlines. Table 4 below lists these aspects of curriculum knowledge.

Pedagogical Knowledge
Again the same set of items concerning pedagogical knowledge was used with each set of respondents. These were derived from contemporary Australian curricular emphases, from recent policy documents (about computers, calculators, gender, disabilities), and from current knowledge of the relation between teaching and learning. (Table 5).

If we had been constructing the sets of items later in the Review we would certainly have tried to include more items that addressed the linkages between the three sorts of knowledge discussed above. Our failure to do so severely limits the extent to which we have contributed to the contemporary research interests in the "pedagogical content knowledge" of science teachers (Wilson, Shulman & Riebert 1987, Ingvarson, Note 1), in the conceptions exit students have of science teaching (Baird et al. 1987) and the change process in science teacher education (Northfield, 1986).

METHOD

So that the survey of exit students concerning these knowledge areas would provide maximum information and make sense to the student respondents, it was necessary to design five questionnaires. These recognised the distinctive kinds of pre-service programmes in Australia and in the way detailed aspects of the respondents' confidence of the three sorts of knowledge could be expected in them. The questionnaires also contained items on the respondents' school backgrounds in mathematics and science, their socio-economic status backgrounds, their reasons for undertaking teacher education, etc. In most cases they were administered in class by the institutional staff and mailed follow-ups were used. In some institutions, students in October 1988 were already on final teaching practice from which they would not return to college. Response rates varied considerably but generally were around 60 - 70%. In a small number of institutions where the response rates were very low a second survey was carried out in 1989.

Interpreting results

There are difficulties in interpreting student responses of this type. In particular the validity of using the aggregated results of a student sub-population as a measure of their programme's worth is problematic. Students' responses to the sorts of items they were asked may not be valid measures of their actual knowledge or confidence in practice. It is a large inference to move from measures of students' strengths and weaknesses to a programme's strengths and weaknesses. Some programmes may be dealing with students whose backgrounds and abilities enable them to respond more easily to the programme's teaching. Summary statements of the responses such as a mean (or average) value of some response category can also be a blunt measure from which to draw absolute or relative inferences about programmes.

The students' responses are likely to be based on their experience in their practica which may not be the same as it would be in a real teaching role. Students may be biased against particular staff or their programme more generally. Students who really know may be more likely to recognise the limits of their knowledge. Some of these sources of invalidity may average out in a national analysis but we could not be sure of this, nor could we check it. We thus analyzed and reported the responses as they were, and we acknowledge that the conclusions, we or others draw, should be in this context of limitation. One final problem is the obvious fact that students can learn (or fail to learn) outside or despite the programme in which they are enrolled.

Judgements about ratings

Four-point scales were used in the knowledge items and the Review Panel took the position that a rating of less than 2.5 represented "poor quality", that 2.5 to 2.75 was "marginal quality", that 2.75 to 3.0 was "acceptable quality" and that more than 3.0 was "good or excellent quality". Statistically the sample sizes were usually over 100 and the standard deviation for an item's responses was about 0.7. Thus a difference of 0.15

between means will be significant (at the 0.05 level). The Panel judged differences of 0.15 to 0.3 to be small but real and greater than 0.3 to be substantial.

FINDINGS

Some examples of the findings for national sub-population preparing for secondary teaching are now presented to indicate the form in which they are available. The complete set of national findings can be found in Volume 2 of the Report. The data for individual institutions were passed on to them together with state and national means for their own comparative purposes. Some of these data will be referred to but are not tabulated here.

Content Knowledge The confidence of the respondents in the broad aspects of science content knowledge is given in Table 1. The responses for the students in the three types of courses preparing secondary teachers are given separately. The 3 year concurrent courses were all offered by CAEs, as were most of the 4 year concurrent ones. Most of the students in 4 year end-on courses were in the established universities of 1988 (that is, before amalgamations).

TABLE 1
MEAN RATINGS OF SECONDARY SCIENCE: CONFIDENCE IN BROAD ASPECTS OF CONTENT KNOWLEDGE

		COURSE TYPE		
		CONCURRENT		END-ON
		3 Yr	4 Yr	
Concerning the subject: science		N=81	N=211	N=650
1.	Understanding basic concepts/principles	3.3	3.4	3.4
2.	Confidence in understanding new ideas	3.2	3.3	3.3
3.	Extent of finding subject exciting	3.1	3.3	3.3
4.	Ability to use primary sources	2.9	3.1	3.2
5.	Ability to use secondary sources	3.2	3.5	3.4
6.	Knowledge about recent advances	2.5	2.5	2.5
7.	Familiar with real world applications	3.1	3.1	3.1
8.	Knowledge of historical development	2.7	2.5	2.5

The students in the two four year course types showed no significant differences, with six aspects above 3.0, but the three year students were significantly below in confidence on their *positive involvement with science* and their *ability to use primary and secondary sources*. Two aspects - *knowledge about recent advances* and *knowledge of historical developments* had values that indicated low quality in all three programmes. The latter is disappointing but not surprising in the light of our other information about these courses. It is disturbing that the end-on students had no more confidence about recent advances in science since they had learnt their science in the context of research-type science departments and generally spent many more hours in lectures and laboratories than their college counterparts. This weakness in undergraduate university science courses has been discussed elsewhere (Fensham, 1990).

In the ten more specific areas of content for teaching, at the Years 9/10 level only (see Table 2) only *real world modelling* stood out as of marginal quality. This is a contemporary interest of some curriculum designers, because of its potential for using computers in science education. It was not a confidence area for students in any of the courses. Despite the evidence the Review Panel was given that modelling with computers is expanding rapidly in science research, we found little evidence of its presence in the science courses these students had studied, unless they had included agricultural science or some of the environmental or earth sciences. The confidence students in all three programmes expressed in *the nature of science* and in *science technology and society* surprise us from the other information we gathered about their courses. Many institution's courses were rated by us poorly on these aspects on the evidence we elicited from them. It may be that the respondents had no real yard sticks for these aspects with which to rate themselves and their expressed confidences would not match well with some new curricula's quite sophisticated expectations for these areas.

The Report has drawn attention to the peculiar demands that the Australian school context places on secondary science teachers to have both depth and breadth in disciplinary knowledge. It indicated that college-based courses were more likely to ensure breadth in students' science studies, since at least some study in biological, physical and earth sciences was often mandatory - a situation that rarely pertained in the university science courses.

TABLE 2
MEAN RATINGS OF SECONDARY SCIENCE:
CONFIDENCE IN CONTENT AREAS (Yr 9-10)

		COURSE TYPE		
		CONCURRENT		END-ON
		3 Yr	4 Yr	
Knowledge to teach Yr 9-10 science		N=81	N=211	N=650
1.	Living things and the environment	3.30	3.38	3.29
2.	The human body and its well being	3.41	3.48	3.39
3.	Materials and their characteristics	2.98	3.11	3.06
4.	Energy and matter	3.08	3.21	3.12
5.	Forces and their effects	2.96	3.01	2.94
6.	Real world modelling	2.76	2.78	2.74
7.	The earth, atmosphere, and space	3.15	3.28	2.96
8.	The processes of science	3.40	3.50	3.47
9.	The nature of science	3.18	3.21	3.25
10.	Science, technology and society	3.09	3.11	3.16

The findings in Table 3 of the respondents' confidences in other disciplines than their major are in general very alarming.

Only the few earth science majors reported good quality knowledge in a disciplinary area other than their own major. Many biology majors would have studied more than one unit of chemistry and indeed could have majored in biochemistry. Yet they show confidence values of 1.92 and 2.51 for chemistry in the two four year course types. Conversely, chemistry majors would often have studied either a biological science or physics at second year level but neither appear with good quality values. Physics majors from either course type are the least confident in their knowledge of other areas, although they are marginally better in the college sector as a result of the common breadth requirement in those courses.

TABLE 3
SECONDARY SCIENCE : CONFIDENCE IN CONTENT AREAS

Knowledge to teach Yr 11-12 in science.

	C	E		C	E
Biology Majors	N=74	N=267	Earth Science Majors	N=21	N=37
1. Biology	3.82	3.71	1. Biology	3.58	2.91
2. Chemistry	1.92	2.51	2. Chemistry	2.00	2.49
3. Environmental Sc.	2.96	3.04	3. Environmental Sc.	3.44	3.41
4. Earth science	2.51	2.30	4. Earth science	3.32	3.50
5. Physics	1.49	1.74	5. Physics	1.68	1.94
Chemistry Majors	N=50	N=215	Physics Majors	N=40	N=89
1. Biology	2.85	2.90	1. Biology	2.21	1.81
2. Chemistry	3.60	3.65	2. Chemistry	2.67	2.65
3. Environmental Sc.	2.52	2.68	3. Environmental Sc.	2.34	2.15
4. Earth science	2.29	2.17	4. Earth science	2.29	2.14
5. Physics	2.19	2.12	5. Physics	3.77	3.80

(C indicates CONCURRENT, 4 yr; E indicates END-ON)

The Report has commented on the absence in Australian courses of minor sequences in science that set out to give an overview of a science discipline. In the USA the Panel was aware that such courses are often provided for the very purpose of establishing the level of confidence our respondents so evidently lacked.

Curriculum Knowledge In the five designated areas of curriculum knowledge only two showed good quality values among the two four year course types and the three year courses were below this standard on all five (see Table 4) even on knowledge of the *relevant state curricula*.

TABLE 4
MEAN RATINGS OF SECONDARY SCIENCE: CONFIDENCE IN CURRICULUM KNOWLEDGE

		COURSE TYPE		
		CONCURRENT		END-ON
		3 Yr	4 Yr	
	Knowledge to teach Yr 12 science	N=110	N=232	N=737
1.	Relevant state curricula	2.59	3.09	3.08
2.	National/international curriculum movements	2.07	2.37	2.39
3.	Develop small curriculum unit yourself	2.66	3.34	3.17
4.	Linkages to other parts of the curriculum	2.44	2.81	2.69
5	Gender factors in science curriculum	2.32	2.98	2.85

The "do-it-yourself" or teacher-based ideas about curriculum that have been strongly promoted in Australia since the late 1960s are evidently being perpetuated in most of the courses. It is, however, disappointing that the high confidence of this knowledge is not associated with knowledge of *national/international movements in curriculum*, or of *links* *to other parts of the curriculum* or of *gender factors*. We must wonder what frameworks these students have to guide their development of small curriculum units, especially as they show little knowledge of *contemporary ideas about learning* (Table 5).

Pedagogical Knowledge In general the respondents' confidence with respect to the twelve areas of pedagogical knowledge are unsatisfactory (see Table 5).

The responses from those in 3-year courses are singularly deficient. The 4-year concurrent students show the best profile, and this is probably due to their more extended contact with these ideas and practices and often with practical teaching. The end-on students were very deficient in *computer-aided methods* and *calculator-based methods* and their science studies have not helped in this area. They have some awareness of the need for *positive discrimination to girls* but are not adequately knowledgeable about how to teach accordingly. All the groups are very poor at knowing how to *teach disabled students* and it would appear that systems may have to take responsibility for this as a specific need in-service if integration policies now in place are to work in science. The strength in knowledge of *didactic methods* is not coupled with knowledge of how students learn.

TABLE 5
MEAN RATINGS OF SECONDARY SCIENCE:
CONFIDENCE IN PEDAGOGY AREAS

		COURSE TYPE		
		CONCURRENT		END-ON
		3 Yr	4 Yr	
Confidence of knowledge to teach to Yr 12		N=110	N=232	N=737
1.	Didactic teaching approaches	3.01	3.43	3.16
2.	Inquiry/discovery methods	2.86	3.12	2.97
3.	Problem based methods	2.72	3.06	2.90
4.	Computer aided methods	2.04	2.51	2.09
5.	Project based methods	2.42	2.88	2.67
6.	Calculator based methods	2.26	2.59	2.24
7.	Constructivist methods	2.69	2.80	2.65
8.	Laboratory approaches	2.64	3.10	3.02
9.	Teach. positively discrim to girls	2.30	2.64	2.60
10.	Teach. assisting disabled students	2.29	2.30	2.16
11.	Teach for indiv. differences	2.64	2.86	2.53
12.	Excursions	2.29	2.74	2.59

Early Childhood/Primary The respondents in these courses only showed good quality content knowledge in *living things and the environment* and in *processes of science*. Even the *human body and its well being* did not average 3.0 or above for any of the institutions. This unsatisfactory state of affairs is not surprising since so little time is devoted to teaching these students science (see Speedie *et al*; 1989, Vol 1. pp 77, 84). It also reflects the unfortunate tendency of these students to have studied only biology in their own schooling after Year 10. That situation must change or these courses must adopt the Report's recommendations about time given to science, if science education at these levels of schooling is to be any more than the Nature Study it was supposed to replace thirty years ago. The relative confidence in *processes of science* is distressing when it is disembodied from the conceptual areas in Table 2. They may know some processes but can they really be processes of science?

Since we were told in most institutions offering these courses that the majority of the time in the inadequate number of units for science/science education was devoted to curriculum/pedagogy the knowledge reported by these students is disappointing in the extreme. Only *linkages to other curriculum* and *inquiry/discovery methods* rate at 3.00 +. This probably reflects the impossibility the course staff face with so little time for science. Confident knowledge for teaching needs to go hand in hand with confidence in one's own scientific knowledge.

Given that the respondents in these courses are at least 85% female, the very low level of knowledge of *positive discrimination to girls* is almost inexcusable. In Vol 1, p 150 we reported with amazement that so few of the staff in early childhood/primary saw the gender bias in their students either as a cause for concern or as an opportunity for very explicit reflection and action on this gender issue.

Institutional responses In the reports on the individual institutions that are reported in Volume 2, the Panel does refer on numerous occasions to the students' responses to the sorts of knowledge and their items. In general, this was only done when the differences between the institution's means and the state or national means were greater than 0.15 although some exceptions were made when all items were above or below but not all differed by 0.15. For the secondary courses which often had small numbers a difference of 0.5 was supplied (stemming from a sample size of 8) so mention is quite rare.

More importantly, however, the Panel did not quote such student-based data and the differences in them unless they coincided with its own judgement about the courses and the programme as a whole from the various other sources it had before it.

During our visits to the institutions in 1989 it was possible to discuss the findings since they had been provided in advance. Quite often the Panel was provided with explanations for the low values associated with various items. Sometimes it was that the content of the item was not relevant to the particular course or that its wording was misunderstood by the students, or that significant sub-groups of students were absent when the data were collected.

These may have been the case, but these problems were never raised in these discussions with respect to items for which a higher than the average value had been reported.

Since the Review, some reports have been received to suggest that a number of institutions have made modifications to their courses in the light of these student responses. We have no basis for knowing how widespread this has been nor how effective the modifications are, but some other investigators (see Symington et al. in this volume) may provide one.

CONCLUSION

Exit students were able to respond differentially to a range of items within the three sorts of knowledge chosen by the Panel as a knowledge framework for future teachers. Their responses showed very different values for students' confidence in the knowledge they had gained as they neared the end of their initial education for teaching.

The findings were in many cases consistent with what could be expected from other information the Panel received about the courses and overall programmes these students had undertaken. A number of deficiencies in the quality of the knowledge acquired were revealed. There was, on the other hand, enough consistency between high mean scores and the emphasis known to exist in particular courses to suggest that the learning experiences offered in courses can be effective.

The extent to which the measures of students that were obtained can be used to infer the quality of programmes and their courses is more problematic, but they are at least worthy of consideration by the staff responsible.

We would suggest that the items could be useful tools to help students articulate (and to reflect on their learning experiences) what indeed they have learnt during their teacher education in science and science education.

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PRIMARY/SECONDARY TRANSITION AND RELATED TEACHER ATTITUDES TO SCIENCE

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ABSTRACT

There is an increasing call for K-12 continuity in education. This is supported by curriculum policy statements that are designed to cut across the traditional lines of discontinuity, particularly the primary/secondary boundary. However, apart from the different curriculum traditions of the two areas (Primary & Secondary), other major differences still remain. One such difference is the generalist training of primary teachers and the subject-based specialist training of their secondary counterparts. Does this result in attitudinal differences in respect to curriculum development and implementation priorities? This paper goes some way to addressing this question and is based upon interview data obtained from both practising teachers and teacher education undergraduates. The data represent two separate stages of research, one completed and one on-going.

INTRODUCTION

Considering most students educated within the various systems of western countries (Australian Council of Educational Research, 1989) experience a 'transition' at some stage from 'generalist' primary, or elementary education to 'specialist' secondary education, surprisingly little research has focussed on this aspect of schooling. Less still has considered the influence of this transition on student attitudes and achievement in specific subject areas such as science. Research-based information that is available suggests it has a considerable, and possibly negative, affect. (Baird, Gunstone, Penna, Fensham, & White, 1990).

In recent times, various state Education Departments have attempted to minimise discontinuity by developing curriculum policy statements not as separate primary/secondary packages, but as inclusive frameworks or guidelines (Education Department of Tasmania, 1987ab; Ministry of Education, 1987; Department of Education and the Arts, 1990). Such a science curriculum rewrite has been underway in Tasmania for the last three years in an attempt to improve curriculum continuity from kindergarten to year eight (K-8), this includes students from age five to fourteen.

The first stage of this study was conducted during 1989 to try to ascertain what consistencies/discrepancies existed in respect to teacher attitudes and philosophies prior to the writing and promotion of a K-8 curriculum statement. The second on-going stage revisits the same issues with teachers after exposure to early drafts of the document and after some school 'clusters' have set up working committees to deal with concerns and issues arising from primary/secondary transition and curriculum continuity. (A school 'cluster' usually consists of a district secondary school and its feeder primary schools.)

STAGE 1 RESEARCH AND FINDINGS

Throughout 1989 a total of forty practising teachers (K-8) and thirty undergraduate teacher education students were interviewed to determine their respective attitudes to science teaching in regard to teaching philosophies, implementation strategies and recent developments and innovations (Ferguson, 1989). The teachers selected were from a range of schools and represented a reasonably even spread across Early Childhood, Primary and Secondary. There was also a wide range in respect to years of teaching. Apart from some attempt to gain this spread of teaching background, selection of individual teachers was random. The undergraduate students similarly ranged across E.C.E., Primary and Secondary and all four years of the B.Ed. program. Data were collected by interview where respondents were asked a set of predetermined questions. As they did so responses were recorded and later read back to the interviewees to ensure a valid representation of their views. At this stage further questions were added where need for clarification arose. The questions focussed on teaching background, priorities in teaching science and reactions to recent curriculum trends.

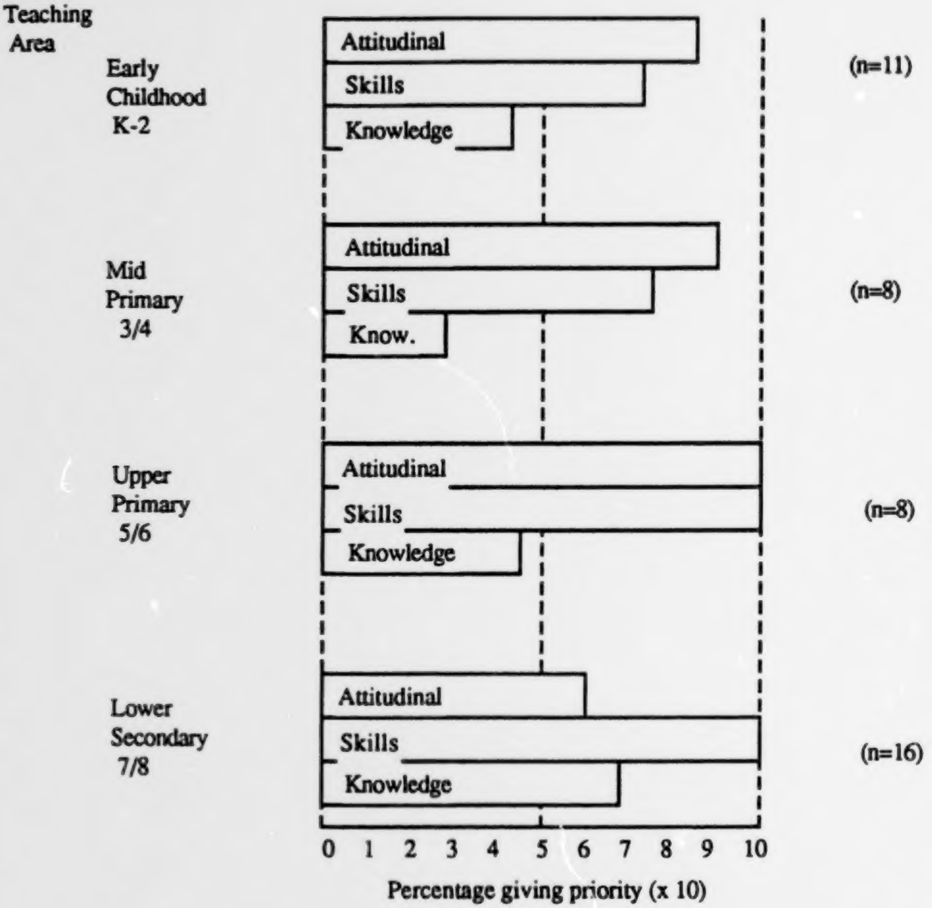

Figure 1: Outcome related priorities of K-8 teachers

A clear pattern arose when responses were analysed. Questions relating to philosophy, implementation and reactions to recent developments elicited a high degree of consistency in response from K-6 teachers regardless of their personal background. The Secondary sample produced responses not only inconsistent with these but also with a high degree of inconsistency within the sample group itself. When asked what were their priorities concerning student outcomes (in respect to science teaching only) all respondents gave some variation of attitudinal, knowledge/concept development and skills development. 'Outcome related priorities' refers to possible outcomes that are given consideration in the planning and implementing of the curriculum. Many secondary teachers stated that good attitudes were an important outcome *but they were not a consideration when curriculum was being planned.* The graphs in Fig 1 give a clear indication of the changing pattern of such priorities across K-8.

Interestingly the wide variation between attitudinal and knowledge outcome priorities was also evident between K-6 and Secondary teacher undergraduates. Formal training appears to re-enforce the traditional priorities, as revealed in Fig. 2:

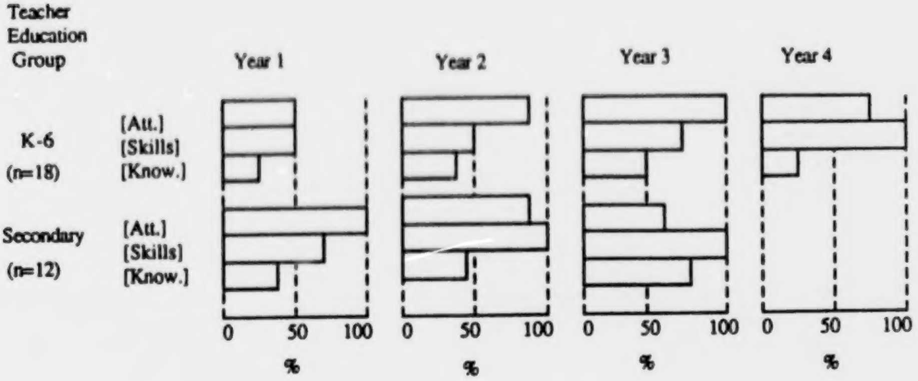

Fig 2: Outcome related teaching priorities of teacher education students.

The term 'Skills' provided a point of difference of interpretation between the K-6 teachers and the Secondary teachers. Invariably the Early Childhood/Primary teachers interpreted the term as meaning 'learning skills' or processes (such as inferring, observing, controlling variables, etc.) whereas the majority of the Secondary teachers interpreted 'skills' as laboratory based techniques or routines (such as 'using a bunsen burner', or 'using a microscope', etc.).

There were many such differing interpretations of terminology within the secondary group and this appeared to have some correlation with the amount of formal science background. The Secondary teaching group was composed of three sub-groups, (although they were all teaching junior science at the time of the interviews):

a) those trained as secondary science specialists,
b) those trained as secondary teachers - but not of science, and
c) those who trained as primary teachers (with science as a major component of their degree) and had subsequently moved into secondary teaching. (Largely as a result of a shortage of specialist secondary science teachers.)

The responses of the three groups are indicated in Fig 3.

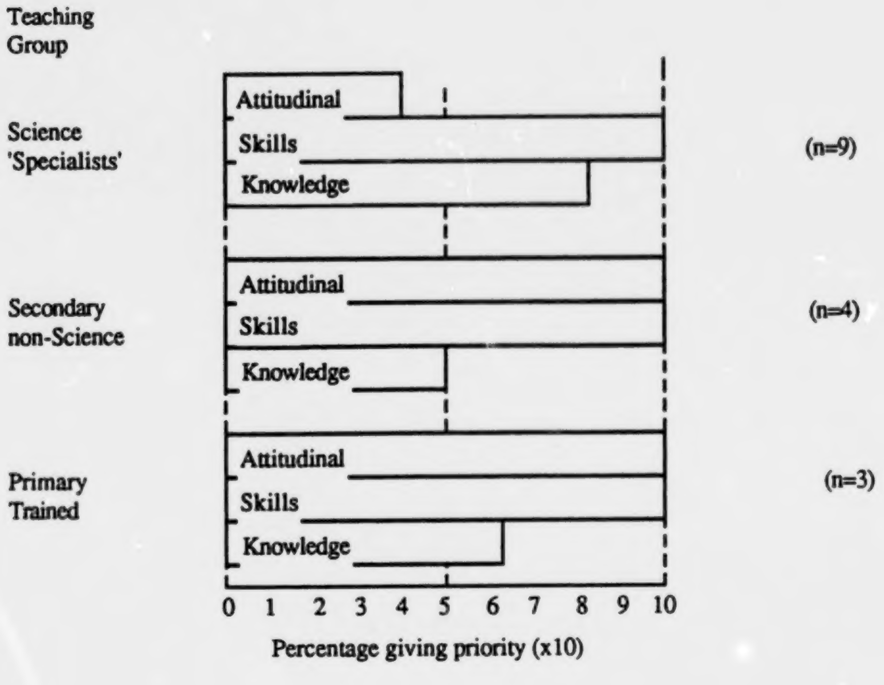

Figure 3: Outcome related priorities of secondary science teachers.

These data, along with the other, more anecdotal, information collected through the interviews suggested that there is a basic difference in science curriculum priorities and approaches in K-6 classes compared with those in Secondary schools. In the K-6 schools, most curriculum decision making is driven by the desire for subject integration and consistency and the needs of students. The curriculum therefore has a student interest and skills development base rather than a content base. There is also great emphasis placed upon across-the-school consistency. K-6 teachers have also expressed a high degree of commitment to the principles of students being responsible for their own learning and "metacognition". The secondary teachers share the long term goal of "students as independent learners" with the K-6 teachers, but these aims often appear to be in conflict with classroom priorities. The content-driven curricula of the secondary school are considerably less flexible and the majority of teachers still interpret their role as one of "decision maker" and "information giver". If this is truly representative of K-8 teachers, it raises many further questions:

Does this create difficulties for students when they transfer from Primary to Secondary School? To what degree does this affect student outcomes? Should such differences occur, and to what degree should curriculum statements, attempting to promote continuity, try to overcome them? What are the implications for teacher education programs?

STAGE 2 ON-GOING RESEARCH

During 1989-90 new Science Guidelines were drafted attempting to provide some curriculum continuity for K-8 Science in Tasmania. A working draft (Department of Education and the Arts, 1990) was completed in December 1990 which was sent to schools for trial and comment during term one of 1991. To gain feedback from interested schools 'cluster' meetings were held in each district around the state where representatives from Secondary schools and their feeder primary schools came to question, discuss and comment on the document. The meetings were chaired by various members of the document writing group.

During this time there was also follow up to the earlier interviews on an individual basis. These were an attempt to determine if differing primary/ secondary priorities created planning/implementation problems - or were even a consideration. There was also some attempt to determine if school 'cluster' committees helped to promote curriculum continuity, particularly in science. (In some districts clusters had been in place since 1989 - or even earlier.) This research is still continuing.

The cluster meetings or forums suggested that not only did implementation strategies and priorities differ from Primary to Secondary but also that these were being driven by deeper differences in teachers' attitudes. Secondary teachers 'appear to have an image of science as a body of knowledge arrived at by the neutral, objective application of the scientific method'(Note 1). By comparison, K-6 teachers describe science as an opportunity for students to work collaboratively through inquiry and problem solving to 'make meaning' of their world. Feedback from the various meetings led the writing party chairperson to claim in his written summary;

> The different images of science and approaches to teaching between K-8 teachers may reflect a variety of views and beliefs about the nature of science as well as the nature and purposes of science education.

These differing views and beliefs manifest themselves in different priorities, educational views and pedagogical practices with the obvious boundary lying between K-6 and Secondary teachers. To a large extent Junior Secondary curriculum decision making appears to be driven by the perceived needs of 'later on' in Upper Secondary classes. K-6 teachers based their decisions more on the perceived immediate needs and interests of the students. Although both groups were positive about the possibility of a greater consistency in curriculum approach across K-8, neither group was happy about the thought of moving toward the practices of the other.

The on-going interviews have already revealed that clusters, at this stage at least, have little bearing on curriculum implementation of informing one group about the classroom practices of the other. Rather, they focus on student orientation days and interpretation of student records, particularly those relating to numeracy and literacy. The interview sample contained seven teachers that are members of cluster committees, however, none knew anything about the science curricula in the other schools in their cluser. Teachers who are not cluster committee members appear unsure even of the function of the groups.

Clearly there exists a considerable difference between K-6 and Secondary teachers' approaches to the science curriculum. If any continuity is to exist, other than on paper, the real nature of these differences needs exploration and research. Such research needs also to consider the educational compatibility of the differing approaches and the affect transition from one to the other has on students' attitudes and capabilities.

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SOCIALLY CONSTRUCTED LEARNING
IN EARLY CHILDHOOD SCIENCE EDUCATION

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ABSTRACT

This paper outlines the findings of a study in which the concept of electricity was introduced to young children in a child care centre. Three areas were examined: first, the perceived difficulties associated with the teaching of science to very young children (3-5 year olds); second, a discussion of the approach used to teach electricity to young children, and finally, the study and its findings. When the teaching of electricity (through a unit on torches) followed a socially constructed approach to learning, all of the children were able to connect up a simple electric circuit and talk about the electricity flowing around the circuit.

INTRODUCTION

A great deal of research has been directed towards children's conceptions of electricity (Tiberghien & Delacote, 1976; Shipstone, 1984, Duit, Jung & von Rhoneck, 1985). Many research projects have sought to find ways to teach this concept to children. However, this effort has been concentrated on upper primary and secondary aged pupils. Yet very young children frequently hear the words 'electricity', 'power' and 'energy'. Most of their constructed environment makes use of electricity. Little is known about how very young children conceptualize scientific phenomena, or how they make sense of electricity in their everyday life.

Shipstone's (1985) review of studies with older children indicates that there are five distinct models of children's representation of direct current (D.C.) circuits. They are, unipolar, clashing currents, attenuation, sharing and the scientific model of D.C. circuit representation. This research indicates that children do have a variety of alternative scientific views which are difficult to modify once formed (Osborne & Freyberg, 1985).

Children's alternative views are believed to be formed by two factors - everyday language that has a different scientific definition and everyday experiences which contradict scientific theories. An interesting example of everyday experiences is cited by Johsua & Dupin (1985; p. 135):

> ...when they consider current conservation in a serial circuit: how can a student explain that the (material) fluid conserves itself and, at the same time, the fluid (of energy) "exhausts" itself little by little? Especially when this last phenomena is so clearly visible (lighting the bulb and wearing of the battery)!

Gilbert, Osborne & Fensham (1982) suggest that many 'words in science are used in an alternative way to everyday language' (p. 625). Children frequently interpret scientific words in terms of their everyday meaning. Conversely words used in everyday discourse can facilitate alternative understandings. In the consumption model of electricity, it can be speculated that phrases such as 'It uses electricity', may give children a consumption model of electricity. Indeed, it can be argued that if teachers do not have knowledge of the particular models of alternative views often expressed by children (or indeed an understanding themselves about the phenomena under study), then they too can be using everyday language for specific scientific terms, thus explicitly encouraging alternative conceptions.

TOWARDS A THEORY OF SOCIALLY CONSTRUCTED LEARNING IN EARLY CHILDHOOD SCIENCE EDUCATION

Science learning in early childhood is better placed within a paradigm in which learning is viewed as being socially constructed. The soviet psychologist Lev Vygotsky argued that children are entrenched in social experiences, many of which they participate in or make use of, but which they do not always understand. These experiences are initially encountered on an interpsychological plane, that is, within the social mores of the particular group. These experiences cannot be understood at the intrapsychological plane (cognitive understanding) without being socially mediated from within the cultural group (Wertsch, 1985). This view of learning emphasizes the importance of the teacher in the education process. It makes explicit the role the teacher takes, and it identifies the teacher as leading conceptual thinking rather than following the children's lead.

Vygotsky has argued that the adult allows the child to work well beyond her/his level (as defined by the child's independent efforts). This process of adult and child working together moves the child through to its zone of proximal development ('the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with a more capable peer', Wertsch, 1985; pp. 67-68).

In Fig. 1 a model of teaching science to early childhood children that incorporates a social construction of learning is presented. Here Bruner and Haste's (1987) scaffolding metaphor as depicted by Cazden (1988) forms the basic building block for science education. A number of levels of scaffolding are presented. They include Field knowledge, Meta knowledge and Society.

Field knowledge includes all the scientific and technological knowledge that has been specifically planned for in the unit of science. In traditional terms it is the 'content' knowledge. Meta knowledge includes all of the process skills and knowledge required for a participant to engage in during the teaching of the unit of science. Two aspects are important here: first the ability of participants to question; investigate and report; and second the ability to understand and take charge of specific genres.

Society includes the explicit realization on the part of the teacher that specific societal values are assumed in the selection of content for investigation. Here teachers can intervene and create learning contexts that address gender inclusiveness and encourage for example, the caring for the natural environment.

In each of the areas of Field knowledge, Meta knowledge and Society, it is not assumed that all areas will require the same levels of scaffolding. Indeed, it can be assumed that when children first encounter early childhood science education, more teacher modelling will be required with Meta knowledge, whilst Field knowledge may need a greater role to be given to the child.

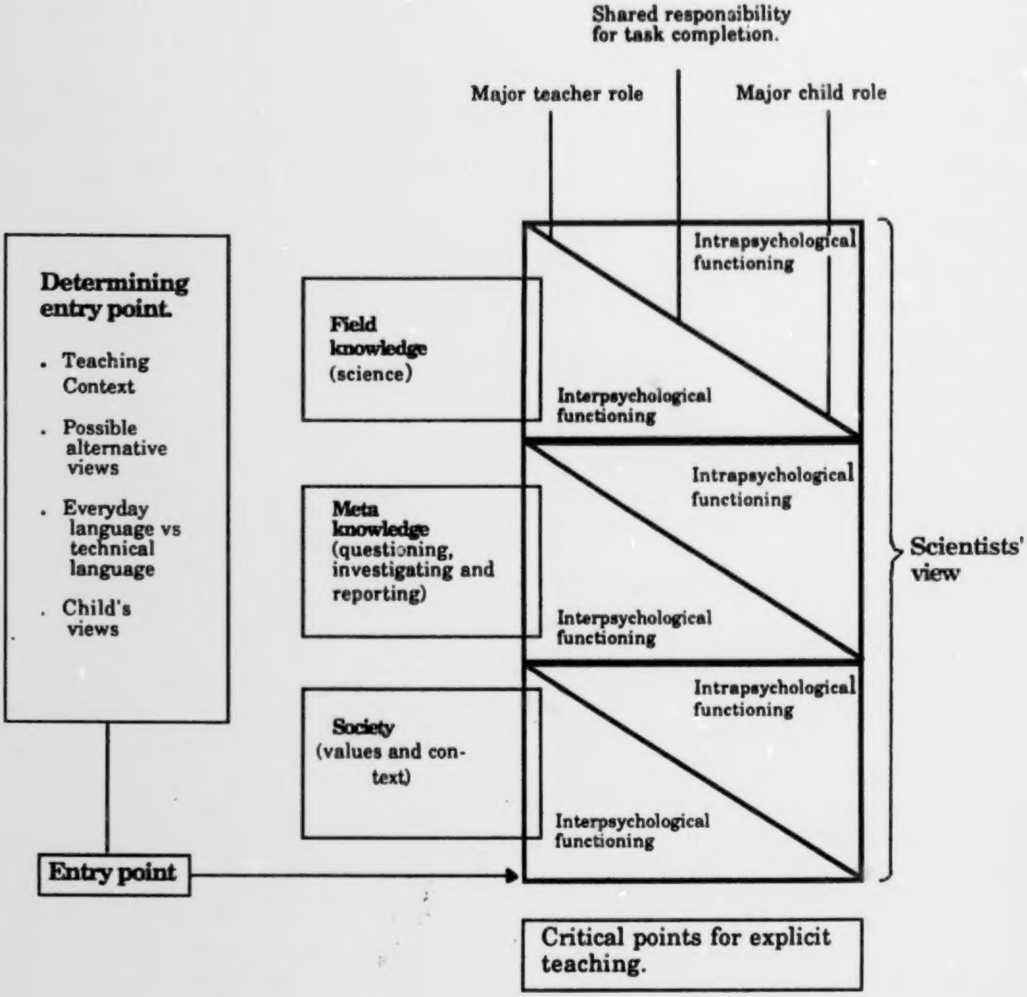
Shared responsibility for task completion.
Major teacher role
Major child role
Determining entry point.
. Teaching Context
. Possible alternative views
. Everyday language vs technical language
. Child's views
Entry point
Field knowledge (science)
Meta knowledge (questioning, investigating and reporting)
Society (values and context)
Intrapsychological functioning
Interpsychological functioning
Intrapsychological functioning
Interpsychological functioning
Intrapsychological functioning
Interpsychological functioning
Scientists' view
Critical points for explicit teaching.

Fig. 1 A model of scaffolded early childhood science education.

Determining the entry point.

It is the teacher's role to scaffold learning for the child so that the child is inducted into scientific understandings found and applied in society. The teacher must determine the entry point for the child by considering four factors: teaching context, possible alternative views, everyday language, and the child's views.

First, the teacher must identify a teaching context for the phenomena under study. It must reflect the child's home experiences in some way so that the child can immediately identify the phenomena under study and bring to it previous experiences. For example in the teaching of electricity, the use of circuits is outside most young children's experiences. However, using torches is not. Contextualizing the teaching experience ensures that the transfer of knowledge and skills is direct and relevant. This approach fits within the child's learning patterns as they occur outside the school environment.

Second, it is important to determine the child's view of the phenomena under study. This factor is well recognized in the interactive approach to teaching science, and most teaching texts for early childhood education (Weber, 1984). When the experiences are familiar, the child is more likely to be able to express her/his ideas. The importance of identifying the children's ideas is well recognized in the literature (Osborne & Freyberg, 1985).

Third, the teacher must identify the possible alternative views that older children seem to acquire about the phenomena under study. If the teacher is aware of the views that children inadvertently acquire, she/he can take steps to ensure against young children developing these ideas, by explicitly imparting information to children at key times during the course of the explorations. For example, in teaching a unit on electricity, once children have successfully identified how to connect up a circuit, the teacher can read to children how the electricity flows around the circuit (since this aspect is not visible). This would ensure that young children are not left to try and come up with a theory for themselves, in which alternative views could be acquired.

Finally, in preparing for the teaching of a specific scientific concept, the teacher needs to examine the possible variations between the technical language and the everyday language. If teachers are aware of problems associated with language, they can take steps to explicitly address possible confusion for children. For example, teachers can explicitly indicate that when a word is used by scientists it takes on a more specific definition. Here children are given the rules for the linguistic games found in speech and texts, and they are better able to cope with the difficulties of the language of science.

Another aspect associated with the use of scientific language, is the everyday language that encourages misconceptions. For example, asking children 'what things use electricity?' encourages a consumption model for thinking about electricity. Teachers who are aware of the alternative views that older children have, can ensure that they carefully structure the lessons to avoid the use of such terms, for example 'What things need electricity to make them work?'

During the teaching of a unit of science it is possible that critical points for explicit teaching may be needed. It is necessary to identify in advance sensitive learning periods in which to introduce factual information. Two different contexts may emerge: first, when scientific theories cannot be easily deduced by the children from their explorations; and second, when misinterpretations can be made easily by children. For example, electrical flow cannot be seen, and as a result information must be given explicitly to children at critical periods during their investigations.

Finally, the role of the teacher is crucial for the success of the approach. The teacher should at all times follow up children's explorations with further questions and factual information. The teacher links the lessons together, prompts the ideas children express, and ensures ideas are shared formally at group time. At all times teachers need to ensure that technical terms are used. Young children do not necessarily need a watered down curriculum. They are not only capable of using technical terms but need these terms to label their experiences so that they can think about them in the absence of concrete materials.

Social construction of learning theory provides a sound basis for teaching science to children as young as three years of age in a child care setting. The present study sought to try out this theoretical approach.

THE STUDY

A group of children (4 year olds; N=16) were involved in a study which incorporated scaffolding techniques discussed above during the teaching-learning process of a series of science based experiences. The experiences consisted of six group times and six free choice sessions over six days. All lessons were audio and video taped (18 hours). Discourse analysis was conducted on all dialogues collected. During free choice time, children could join in the science experiences (coming and going as they wished).

Investigations commenced with the establishment of shared understanding between the teacher and the children through the children manipulating torches and expressing what they knew about them. This was followed by the teacher and the children working together to understand how the torch worked, and later the construction of their own torch using batteries, bulbs and wires.

Within a framework which started with the children's questions, children were moved towards scientific understandings. The teacher modelled the investigation process (based on the children's questions), and over time, the children took on the investigation process themselves. The children connected up the circuit, initially in collaboration with the teacher, but after a period of time, less teacher assistance was given. The children could not only construct their own torch, but modify and extend the experience for themselves without difficulty. Simultaneously children were given direct instruction on how the electricity flowed around the circuit, first, through the reading of factual books, and second, by the teacher outlining electrical flow to individuals as they worked with the materials. The possibility of alternative views caused by confusion between technical terms and everyday terms was explicitly dealt with. In the following transcript, Sam attempts to understand the difference between the technical term of a 'flat' battery with that of the everyday usage of the word 'flat'.

T: Sam, come and tell us some of the things you know about torches? What do you know about how they work?

C: If you leave them on for a long time and you don't turn it off it will just waste.

T: Yes, do you all agree that if you leave the torch on for a long time the batteries will get wasted?
C: No I said forever!
T: Forever, what will happen if you leave it on forever?
C: It will waste.
T: And will it still work?
C2: No.
C3: Or you get new batteries.
C2: They will be flat.
C: (Sam) They won't be flat they'll just be sort of round.
They won't be like that (indicates with hands together).
T: No they won't change shape will they? They won't be flattened down. They'll still be round won't they?
C: They won't be flat like a piece of paper!
T: No they won't, so what do we mean when we say they're flat?
C: You mean they won't work.

At the end of the teaching unit each child was interviewed to determine her/his understandings and asked to connect up a circuit. All children talked about how the electricity continuously flowed around a simple electric circuit, and all children were able to connect up the circuit. In the following excerpt from a whole group discussion, it is clear that Elizabeth has understood current conservation, a sophisticated scientific phenomena, normally not fully understood by children and even some adults.

T: And goes where? It goes from the battery along the wire to?
C: The light bulb
T: The light bulb, and then where? Here's our picture of it all. It starts in the battery and goes along the wire to the light bulb and then where?
C: Battery
C: Back to the battery
C: (E) And it makes it better and puts it away again
T: What was that Elizabeth?
C: (E) It makes it good again and then puts it back and then throws it away again.
T: Yes the electricity goes round and round in a circuit

Towards the end of the teaching unit, the teacher prompted children at group time to express their understandings:

T: We're going to try and think of all the things that we know about batteries and torches and electricity. Do you think you can remember all those things you know?
C: Yes
C: How much is there?
T: I'm looking for people who can tell me what's inside a torch.
C: Batteries
C: Wires
C: Light bulb
C: A spring
T: I think that's all.
C: No that thing, the black one up the top

T: What could we call it? That's the part that attaches to the light bulb.
Now, what's inside a battery?
C: Electricity
T: When we pulled apart the battery what did we see inside it?
C: Black stuff
T: Yes the black paste
And what's this part called?
C: Carbon rod
T: And what's the funny name for this outside part of the battery. Zzz?
C: Zinc
T: That's right there's a zinc case.

The children freely recalled the names of items they had been investigating. With less familiar terms such as zinc, appropriate teacher prompting assisted with recall. Whilst group discussions do not reflect individual children's conceptual development, the views expressed above were representative of the views obtained from interview data with children on a one-to-one basis.

At the conclusion of the experiences with the torches (12 sessions over 6 days) and over two months later, the children were re-interviewed and once again asked to connect up a circuit. In addition, children were asked to draw their circuit. All children easily connected up the circuit and all children were able to explain that the electricity flowed around the circuit. Most children were able to draw their circuit.

The adult-child interaction evident throughout the unit on torches focused on extending the children's cognitive understanding of the materials they were manipulating. This was achieved by commencing explorations from within a socially meaningful context, namely torches, and moving to an abstract context and understanding (through the use of circuit materials). This movement in thinking was only possible through the carefully planned and implemented adult-child interaction.

Adult-child interaction throughout the unit featured many of the traditional interaction types such as questioning and procedural interaction. However, what was significant and different to most learning contexts was the greater emphasis placed on joint exploration and task completion and direct instruction (abstract-based) during explorations with the materials. Children were given information that moved them from the concrete to the abstract, first in a concrete context (as they worked with the materials) and later in an abstract context (during group time, when felt board props or circuit diagrams were used). These information sharing sessions were repeated many times, without loss of interest by the children. The success of this approach is evident in the cognitive attainment of the children as outlined above. Indeed what is now clear, is that children are most receptive to learning experiences which help them to understand everyday phenomena no matter how difficult the concepts are perceived to be by the adult world.

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A STUDY OF CONCEPTUAL DEVELOPMENT IN EARLY CHILDHOOD.

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ABSTRACT.

This paper reports part of a study which investigated young children's conceptions of scientific and technological phenomena and the conceptual change that occurs during the teaching of science in pre-school, Transition/Year One and Year Two/Three classrooms. Science lessons from each school/centre were audio and video taped for a period of six months. Informal interviewing of teachers occurred in direct response to lessons observed. Informal interviewing of children was conducted to determine current scientific thinking in relation to the science lessons presented by the teacher.

Two main elements emerged. First, different types of teacher-child interactions were evident during the science lessons observed and it was found that specifically focused interactions led to conceptual development in young children. Second, children's views (whether scientific or not) were maintained over a three month period.

INTRODUCTION

Science and technology education in the early childhood years (pre-school, kindergarten and years one to three) has received minimal attention from the general education community (ERIC search 1980-1990). Limited formal time within the curriculum is devoted to this area, and a correspondingly small amount of teaching has resulted (Symington & Hayes, 1989).

Relatively few research initiatives have been directed towards science and technology education for three to eight year olds (ERIC search 1980-1990). Consequently, little is known about the development of young children's conceptions of scientific and technological phenomena, or indeed of how to teach science to this age group. This is of interest since pre-school education is generally the first formal contact children have with science and technology education.

It is timely that a study of young children's conceptions of scientific and technological phenomena and the conceptual changes that occur during the teaching of science be conducted. Through such research it is possible to develop an understanding of how children acquire scientific and technological ideas and also to gain insights into better ways to teach science to this age group.

This paper will review studies on science education pertinent to early childhood, (particularly, alternative conceptions theory). It will then outline the methodology and procedure adopted by the study, and finally present the findings.

ALTERNATIVE CONCEPTIONS THEORY

Research activity since the early 1980's has centred around children's construction of scientific meaning (Gunstone, 1988). Osborne and Wittrock (1985) identified two areas of interest:

- the conceptions of the natural and physical environment which children bring with them to science lessons; and
- the impact of science lessons on those ideas (p. 59).

This focused attention on children's construction of science has led to intense research activity generating large scale research projects (Baird & Mitchell, 1986), conference papers and articles (for example Duit, Jung & von Rhoneck, 1985; Champagne, Gunstone, & Klopfer, 1983) and a number of specialized books (Pines and West, 1985; Driver, 1983; Osborne & Freyberg, 1985; Fensham, 1988).

Carey (1986) draws our attention to the wealth of research conducted on children's views about living and non-living; weight and density; heat and temperature; light; electric current; and force. Osborne and Freyberg (1985) confirm and extend this range to include: changes of state of water; dissolving; burning and rusting; soil; rocks and minerals; and weather. This research indicates that children do have a variety of alternative scientific views which are difficult to modify once formed (Osborne and Freyberg, 1985).

There is an extensive body of literature available to support the premise that children have and do develop alternative conceptions of science to that which are taught in schools (Driver, 1988). The plethora of research has concentrated on primary and secondary children's understanding of scientific phenomena. The early childhood age group has not received this attention and therefore little information is available to guide educationalists working with young children.

THE STUDY

The purpose of this study was two-fold: first, to document young children's understanding of scientific and technological phenomena and determine if they hold alternative views to those generally recognized by the scientific community, and second to ascertain those techniques which change young children's understanding of scientific and technological phenomena to those recognized by the scientific community.

Three teachers and their students from the Australian Capital Territory who were using an interactive approach to teaching science (Biddulph & Osborne, 1984) participated in the study. Only the data obtained from the Transition/Year One teacher are reported in this paper.

The ethnography of communication or discourse analysis, was the research methodology employed. The study of academic learning within the context of normal classroom discourse allowed the researcher to record and analyse conversational support from teachers and determine which structures facilitated the learners' development. In this study, teacher conversational support and classroom structure during science lessons was analysed and related to students' conceptual understanding of the scientific phenomena. This technique allowed the researcher to develop an understanding not only of how teachers identified young children's scientific ideas, but how they set about changing their understandings to be more scientific. In this way it was possible to collect and analyse data within a preliterate culture.

Science lessons from each school/centre were audio and video taped for a period of six months. Informal interviewing of teachers occurred in direct response to lessons observed. Informal interviewing of children was conducted to determine current thinking in relation to the science lessons presented by the teacher. More data were collected from the Transition/Year One classroom. Only data from the third topic investigated (torches) are reported in this paper.

Research into children's scientific understandings during the teaching of the unit on 'torches' constituted an intensive data collection period. Two video cameras and two audio recorders were used to collect teacher-child discourse and visual details of children's interactions with materials. The principal researcher and a technical assistant interviewed the children as they participated in the scientific experiences. In each lesson, the teacher's interactions were recorded, and the children were interviewed about what they were investigating and thinking, and their findings. During investigation time, random samples of children's interactions with each other were also audio taped.

Transcriptions of all interactions and interviews at the end of each science lesson enabled the researcher to follow up on particular children in subsequent lessons. The unit on 'torches' was taught over four weeks, in seven lessons, each lasting approximately one hour. At the end of the unit on 'torches', it was possible to build a profile of each child's development and understanding of what they had been investigating. This information was used as a basis for interviewing the children three months after the completion of the unit. Each child was interviewed about their understandings of the particular questions they had been investigating or the concepts learned vicariously. In particular children were asked to connect up a circuit and explain to the researcher how the torch worked.

TEACHER-CHILD INTERACTIONS

This study found evidence of specific types of teacher-child interaction which promoted conceptual change, resulting in a greater understanding of the teacher's role in the teaching-learning process. In examining learning situations where children's conceptual change was occurring, it was possible to identify a range of strategies that promoted conceptual change. Examples are given below to illustrate the different interaction types documented. The transcripts presented in this paper are typical of the type of interaction that occurred in the Transition/Year One classroom.

The teacher-child interactions changed over time. A number of significant categories of interaction were observed, for example assistance with developing scientific questions, considering and organizing investigations, and the reporting of results. These types are illustrated below.

1. Developing scientific questions

In many instances, children had great difficulty identifying investigable questions. It was through carefully designed interaction between teacher and child that an understanding of the areas of interest or deficit could be ascertained. An example of the teacher probing the child's thinking and guiding the child to an investigable question during a unit of science based on the exploration of 'torches' is shown below.

T: Kai, what do you think you might like to find out? Turn over your page, what might you like to find out?
C: I don't know really.
T: Do you know everything about torches?
C: I know some things.
T: Do you know how they work?
C: Mm.
T: Do you know what they're made out of?
C: They're made out of um plastic.
T: All of them?
C: And metal and wood.
T: What about the batteries, do you know everything about the batteries?
C: They've got acid inside them.
T: Mm, anything else?
C: Um.
T: How do they work?
C: Well.
T: Do you know everything about how they work? Do you know what else is in them besides acid?
C: Um.
T: Have you seen inside them?
C: Yes.
T: What do they look like?
C: They've got skin and they've got things like this.
T: Inside it, have you looked inside the battery?
C: No.
T: Well how do you know it's got acid inside it?
C: Daddy told me.
T: Your daddy told you? Oh, well do you know what else is inside it?
C: Nope.
T: How about you find out about what's inside a battery then?
C: Mm (1.5.90).

2. Modelling of the investigation process

The second type of interaction observed involved the teacher helping children with planning their investigations. During group time the Transition/Year One teacher read out individual questions, carefully naming all individuals who had the same or a similar question. Once small groups were identified, the teacher asked individuals from specific groups how they might conduct their investigations. The teacher then directed their attention to the resources they named or had not thought of, for example "They may help you with your experiment". The teacher frequently provided children with the materials required to test out their questions, as is evident in the underlined section of the following transcript.

(Teacher reading out children's questions. Children sitting on the mat.)
T: I didn't have time to put up everybody's questions, the ones we worked out this morning, let's have a quick look at the ones we were looking at this morning.
Vicki's question: Why does the light go on?
Think about how we can work these out while you are looking.
Mehwash's question: Why do torches need switches to switch them on?
Mehwash you might be able to take a torch and find that out.
Thomas: Can they go by battery power? How do you make batteries?
Stephanie: Why do torches have batteries?
Neils: How does the battery make the torch shine?
Jeremy: How much does the bulb weight and how much does the torch weight? Jeremy, I have put some scales between you and Kerri, because Kerri wants to do some weighing things too.
If you throw a battery in the fire would it blow up? That's yours isn't it Kai?
C: Yes.
T: I don't think we will be able to do that experiment today, but we might be able to find it in a book.
And is there acid in a battery? Is that yours James?
C: No that's mine (Kai).
T: That's yours Kai, we might be able to work that out today.
Bevan: Does a flat battery weigh less than a not so flat battery?
Bevan in the torch that's on your table, there are some batteries that are flat, test it before to see if they are really flat, and new packet of batteries that have not been opened. They should be good ones and some scales.
C: Can I open them?
T: Yes and there are some scales there, so you should be able to work out your question.
Laurel: Can rechargeable torches break? I've got one for you to look at.
Sarah: Why do batteries work? You might be able to look at the batteries, and I have got some that are cut open here, you might like to have a look inside them to see what's in them. There are also some things in the book, about how they work.
Brigit: The glass part is hot, you can melt butter if you shine a torch on it? Brigit on your table is a container with some butter for you to try out.
Kai, what's inside a battery?
Some batteries cut open here for you to have a look at Kai (7.5.90).

The following transcript demonstrates the way in which the teacher used children in her class as models of how to set up and implement the investigation. Mehwash's discovery is presented to the whole class by first encouraging Mehwash to share her findings and second, through the teacher re-phrasing and directing this information to specific children. The Transition/Year One teacher draws the whole class's attention to Mehwash's discovery of the circuit inside the torch. She uses Mehwash as a model to assist other children still grappling with the circuitry involved in constructing a torch.

T: Mehwash found out some very interesting things. I will give you the torch so that you can tell the children what you found out (hands over clear casing type torch).

C: I found out the metal things, goes through the batteries when it touches this white thing, or you can put the torch on, it turns on.

T: It turns on. What happens if that metal part's not touching up to the metal at the top?

C: It won't turn on.

T: So Tristan, did that give you a clue about how to make a torch?
Do you know what you might have to do?

C: Not yet.

T: Not yet, you had one piece with the wire on the battery and one piece to the light, did you have anything that was coming all the way around here, like Mehwash was telling here, that the wire, that the metal bit goes through the middle of the torches and back. Can you think what you might like to do? (8.5.90)

3. The reporting process

The final type of interaction evident in the classroom occurred during the reporting process. Two transcripts are presented here. In the first transcript the teacher helps the children to express their findings. She focuses their attention on the research question, details of the procedure and then the findings. In the transcript of the children reporting on the second day, it is evident that they were able to present their findings in an accurate and more detailed account then possible the day before.

Day One:

T Kerri what did you find out?

C1: The torch weighs 400.

T: You counted up to 400 on the scale, and there was one more group of people, there was Lauren, and Bevan, What did you find out?

C2: The battery what is flat, weigh the same as the flat batteries.

T: Lauren can you tell the children how you and Bevan found that out?

C2: Cause they weight the same amount.

T: But how did you find out that they weigh the same amount?

C2: Cause they pointed to the same number.

T: What did?

C2: The scales.

T: The children didn't see what you did. Can you tell them what you did? What did you have? You had a flat battery, and a not flat battery, and what else did you have?

C2: Scales.

T: And what did you do?

C2: We put them both on...

T: Both on at the same time?

C2: No.

T: Well what did you do?

C2: We put the flat battery on. It weighed four and the not flat battery weighed four.

T: So you decided they weighed the same.
C2: Umm (7.5).

Day Two:
T: Lauren and Bevan, I wondered if you two could start off by telling us what you were doing yesterday?
C2: Umm, weighing the batteries.
T: And what did you do to do that?
C2: We put the flat battery first and it weighed 4 and the not flat battery and it weighed 4.
T: What were you trying to prove?
C3: If it weighed...
C2: If the um flat batteries could weigh um higher than flat ones.
T: You think they would weigh more than flat ones, and did they?
C2: No (8.5.90).

Three types of interaction were identified in this study:

1. The construction of investigable questions;
2. Teacher modelling of the investigation process; and
3. Reframing the reporting process.

It became evident throughout the science lessons that the teacher was interacting in a variety of ways, which led to the overall development of children's ideas.

ALTERNATIVE CONCEPTIONS

When each child's general understandings at the end of the unit was compared with her/his views after three months, most of the ideas were unchanged. Of the 24 children, 19 maintained their views, two changed to some extent and three responses were inconclusive.

An area that most children either directly or vicariously learnt about was how to connect up a circuit. Not all children recorded their views about electrical flow in their thinking books (a blank book that children recorded their prior ideas, their questions, and their results), or expressed their views during the interviews of what they understood. Consequently, comparisons in relation to their ideas of electrical flow were not always possible.

The teacher actively worked children towards a conceptual understanding of electricity by first: helping those that were interested in making torches to connect up a circuit; and second, promoting a view in which electricity continuously flowed from the battery to the bulb and back to the battery again. The teacher did not discuss with the children what electricity actually is.

All children with comparison data expressed exactly the same view of 'electricity' in both interviews. Four children held the view that 'electricity' flowed from the battery to the globe via one wire (unipolar model). Eleven held the view that the 'electricity' flowed from the battery to globe via both wires (clashing currents model), and six children held the view that 'electricity' continuously flowed from the battery to the globe and back to the battery. Two children with this view of 'electricity' moved schools after the completion of the unit and were not available for the final interviewing. If they had been included in the sample (assuming they also retained their views), then one third of the children in the class interviewed would have demonstrated this idea of electrical flow around a circuit.

Observations made during the unit showed that not one child could connect up the circuit when the materials were introduced. Fifteen of the 24 children interviewed were able to connect an electrical circuit with ease. Three required some form of prompting, three connected only one wire, three added too many wires and one could not connect the circuit.

Overall, the findings of this in-depth analysis would indicate that almost all of the children in the classroom under study retained the views they had formed three months after the unit had been taught. Given the age group of the children, three months would be a sufficient time frame in which to assess the maintenance of their views. The learners had retained the concepts learnt long after the unit of science was originally conducted. Although the views expressed were not always consistent with the scientifically accepted ideas, the children's views were retained.

It is interesting to note that research into young children's conceptions of scientific phenomena is not common. It is clear through the results of this study that very young children are able to conceptualize sophisticated ideas such as electrical flow. Indeed this study has demonstrated the interesting results that can be obtained when young children are given the opportunity to engage in scientific tasks often thought to be outside of their conceptual understanding. The results of this study draw researchers' attention to the need to re-focus their research interests, and educational practitioners to the need to re-examine their expectations and curriculum content. It might be that abstract concepts are indeed within the grasp of some early childhood children.

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GENDER, PRE-SERVICE TEACHERS AND ASSESSMENT OF PUPIL WORK

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ABSTRACT

Across Australia fewer females choose to study the physical sciences and their achievements are lower than for males. Many reasons have been put forward for this. Elsewhere science teachers have been found to hold gender-stereotyped expectations of their pupils and to assess pupil capabilities differently according to the gender of the pupil. The gender of the teacher has also been found to affect the assessments made. This study investigated whether pre-service teachers would assess pupil capability across a range of work samples and potential in science differently according to the gender of the pupil or the gender of the pre-service teacher. No statistically significant differences were found for the assessments made. Weak trends in the data along gender-stereotypic lines were found which have implications for teacher training courses. Correlational findings also revealed worrying trends relating forms of assessment with assessment of pupil capability and potential.

INTRODUCTION

Current Australian government rhetoric revolves around Australia becoming the 'clever' country. Whilst retention rates to Year 12 and the number of tertiary places both continue to rise across Australia, the number of students choosing to study science at tertiary level has declined (de Laeter et al., 1989). Concern abounds in scientific and educational circles about the number and quality of students undertaking science-related courses of study on which the future of the nation is said to depend. The under-representation of females in the fields of mathematics and physical science continues to be of concern (DEET, 1989).

Numerous reports and policy statements have been written about females' educational disadvantage with regard to mathematics and science (see for example: Australian Education Council, 1985; Commonwealth Schools Commission, 1984, 1986; Australian Science Teachers Association, 1987). Outstanding curriculum initiatives and resource materials that focus on increasing female participation are available for teachers (see for example: Ministry of Education, 1988; Lewis & Davies, 1988; McClintock Collective, 1988). Year 12 female participation has increased dramatically over recent years (from 48% of all year 12 students in Victoria in 1973 to 58% in 1989). Despite all of these factors, females continue to remain under-represented in the physical sciences.

THE LITERATURE

The literature reveals a plethora of factors contributing to the under-representation and lower achievement of females in mathematics and science. Mathematics and physical science are still very much stereotyped as 'male domains'; from science text books (Ives, 1984), classroom display materials (Jones & Wheatley, 1989), children's and pre-service teachers' 'images of a scientist' (Kahle, 1988), to its total packaging (Kelly, 1987). Gender differences in motivation, attitudes towards and confidence in mathematics and science are found to contribute to females' lower participation in these fields of study both at higher secondary and tertiary levels (Armstrong & Price, 1982; Fennema & Sherman, 1977, 1978; Leder, 1982, 1985; Murphy, 1978; Wolleat et al., 1980; Pedro et al., 1981). Gender-stereotyped differences in interest in the science disciplines have been found to affect enrolment patterns, as do peer group pressure, perceived difficulty of subjects and career relevance (de Laeter et al. 1989). These differences in interest have also been found to affect career aspirations (Parker & Offer, 1987). Past performance in science is found to be associated with previous and subsequent performance (Rennie & Punch, 1984).

In mathematics and science classrooms, males and females are found to receive differential treatment from teachers (Spender, 1980; Crossman, 1987; Leder, 1988). Teachers have been found to hold gender-stereotyped attitudes towards their students' future careers (Evans, 1979, 1982; Moore & Johnson, 1983), to the female role (Spear, 1985) and to the realisation of students' full potential (Open University, 1986). Teachers have been found to prefer dependent rather than aggressive female students (Jones & Wheatley, 1988) and to prefer teaching boys (Open University, 1986). Teachers of gender-stereotyped subjects show least sympathy towards equal opportunity (Pratt, 1985) with male teachers being less sympathetic (Adams, 1985). Science is also believed to be more important for boys (Spear, 1987).

Teachers and bias in science assessment

Bias can be built into tests (Murphy, 1978) which can affect results for males and females. For biology in Britain (Harding, 1983) and for VCE level physics in Victoria (VCAB, 1988, 1989) it has been found that males perform better on multiple-choice and answer only items; females perform better on extended answer questions.

Spear (1984) reported that science teachers assessed identical student work samples differently and held differential expectations for pupil potential according to the gender of the student. Teachers have also been found to attribute gender differences in performance beyond themselves (Open University, 1986; Bradley, 1984) although they see successful academic achievement as consistent with the male stereotype. When names appeared on examination papers, second examiners who did not know the students exhibited gender-bias in their assessments (Bradley, 1984). Essays of unknown students when attributed to females were consistently scored lower than when attributed to males (Jones, 1989).

Pre-service teachers

Very little is known about pre-service teachers regarding gender issues in science. Christensen and Massey (1989) found education students' attitudes towards traditional sex roles were as stereotyped as the rest of the community. Kahle (1988) reported that 82% of pre-service teachers who were asked to "draw a scientist" produced white males. Texts used in teacher education programs have been found not to contain information on countering sexism in the classroom (Jones, 1989) with only one third even mentioning sexism. Of these very few were in mathematics and science methods texts. Seven times as much space was found to be devoted to males as to females in the science method texts (Jones, 1989).

The Discipline Review on teacher education in mathematics and science found that few teacher training courses included gender issues as an integrated and significant component of the curriculum. Only six institutions surveyed had programs in which "gender inclusiveness was both included and practiced" (Fensham & West, 1990, p. 94). The category in which the least number of institutions provided well and for which the highest number of institutions were found to do nothing was 'gender'. Academic staff were not overly concerned about issues relating to gender; staffing revealed an imbalance in male and female presence in mathematics and science departments particularly at the more senior levels of appointment (DEET, 1989).

The situation with regard to gender issues within teacher education programs seemed to indicate that a study of pre-service teachers' attitudes to a gender-related issue in science education was needed. From Spear's (1984) findings, assessment was an area inviting investigation.

THE STUDY

This study was designed to ascertain whether pre-service teachers of physics and science would assess pupil work samples and potential in science differently according to the gender of the pupil and whether pre-service teacher gender made a difference to the assessments made.

Participants

The participants in the study were the Monash University Diploma in Education (Dip.Ed.) students in the physics and science methods classes. The total number of participants was 26 (16 male and 10 female): of the 26 students, 10 were from physics method (8 male and 2 female) and 16 were science method students (8 male and 8 female).

Method

Work samples from year 10 pupils from one class in a co-educational secondary school studying the Shanks (1981) physics-related unit "Science and the road - the vehicle" were collected. The work samples were authentic: they were not specifically designed for the study and formed an integral part of the teacher's program for the unit.

The work samples

Three different pieces of work were collected:

Work sample 1: Five questions relating to car safety features which required written responses.

Work sample 2: A formal practical report of an experiment, in two parts, on static friction.

Work sample 3: An end-of-unit test which included a range of question types: multiple choice items, definitions of terms, short answer questions and one mathematically based interpretation question.

The three work samples were collected from twelve pupils. Six were selected for the study and these appeared to reflect the full ability range of pupils in the class. Fictitious names were assigned to the work samples. The fictitious names had been written out in each pupil's own handwriting.

The tasks for the pre-service teachers

The pre-service teachers were informed that the study was related to assessment in science: no mention was made at the time of data collection that gender issues were involved since it was believed that this might bias the results. The pre-service teachers were informed about this at a de-briefing session held later. In order to ensure that the students did not engage in discussions and thus inadvertently stumble on the changes in fictitious genders of the pupils' work they were assessing, they were informed that individual rather than collaborative assessments were needed for a valid analysis to be able to be undertaken. At the de-briefing, the students indicated that they had found the tasks very difficult and had no inkling that gender was an issue of interest.

Each pre-service teacher assessed the work of all six pupils: three fictitious females and three fictitious males. In all, twenty combinations of three males and three females amongst six pupils are possible. All twenty combinations were used: the remaining six needed were randomly selected and assigned to the pre-service teachers. This meant that each pupil's work was assessed approximately thirteen times as being the work of a male pupil and thirteen times as being that of a female pupil.

A marking scheme was prepared and given to the pre-service teachers. A sheet was prepared on which the students recorded their assessment of each pupil's work. The sheet was individualised for each pupil by using the pupil's (fictitious) name throughout. This was done to draw further attention to the fictitious gender of the pupil whose work was being assessed.

The task requirements

1. For Work Sample 1, a global score out of 10 was assigned to the responses to the five questions on car safety features.
2. For Work Sample 2, the practical report, nine criteria were established: aims clearly stated; method clearly defined; observations/results clearly recorded; data appropriately graphed; calculations accurately performed; data interpretation/analysis competently done; conclusion appropriate; scientific language and units appropriately used; and presentation neat. Each criterion was scored on a 5-point scale, where 5 indicated very high attainment of the criterion and 1 indicated very poor attainment.
3. For Work Sample 3, the end-of-unit test, marks were assigned to each question and recorded. A total score out of 25 was then arrived at.
4. The pre-service teachers also assessed each pupil's potential to pursue further studies in science. Six statements were rated on a 5-point Likert-type scale to which students indicated their agreement (from SA (Strongly Agree) to SD (Strongly Disagree)).
   e.g. I would recommend that (pupil name) study physics in year 11.
5. Finally, each pre-service teacher ranked the six pupils on science achievement. The ranking was based on the assessments made on the three work samples for each pupil.

Data analysis

For each of the work samples, the score on the potential in science scale and pupil rank, a 6 x 2 x 2 factorial design was set up and a three-way Analysis of Variance (ANOVA) was carried out using the SPSSx software package. The hypotheses tested at the $p<.05$ level were that the mean scores attained would differ according to:

- ascribed pupil gender and
- pre-service teacher gender.

Patterns of responses were investigated on the assessment criteria for the practical report and on the individual questions which made up the end-of-unit test. The data were also explored in relation to highest and lowest achieving pupil and by mean scores across pupils by work sample type. Pearson correlation co-efficients were found across the assessment tasks and comparisons were made.

Results and discussion

For each of the three work samples (the written responses, the practical report and the end-of-unit test) the ANOVA results indicated that the ratings given to the six pupils' work differed ($p < .001$). This was to be expected: it shows that the pre-service teachers recognised the intended differences in quality of work.

No statistically significant differences were discernible when either ascribed pupil gender or pre-service teacher gender was considered. This would appear to indicate that neither pupil gender nor pre-service teacher gender influenced the assessments made of the level of achievement on the six pupils' work for each work sample. However, when two-way interactions of variables were considered, all four ANOVA's revealed lowest p-values for the interaction of pupil with ascribed pupil gender although none reached the .05 level.

The potential to pursue studies in science scale, as a whole, was found to be internally consistent (Cronbach's Alpha = 0.85). Again, no statistically significant differences in mean scores were found when either ascribed pupil gender or pre-service teacher gender was considered. When mean pupil rank was analysed, the ANOVA again showed no statistically significant differences by ascribed pupil gender or pre-service teacher gender.

When the scores for the separate criteria for the practical report were examined by ascribed pupil gender, some weak trends were evident in gender-stereotypic directions for some of them.

- "presentation neat" - five out of the six pupils received higher mean scores when the ascribed pupil gender was female (cf. Spear's (1987) finding that science teachers in Britain scored fictitious females more highly on 'neatness')
- "method clear" - five out of the six pupils received higher mean scores when the ascribed gender was male (cf. gender-stereotypic expectations that males are more logical and methodical than women).

There were no discernible patterns when the mean scores by individual question on the end-of-unit test were considered.

In all, the statistical procedures employed would appear to indicate that for this sample of science and physics pre-service teachers who assessed the three work samples of the six unknown pupils according to the assessment criteria laid down, neither the gender of the pupil nor the gender of the pre-service teacher affected either the assessments made of the pupils' achievement levels on the work samples, the perceptions of potential to pursue future studies in science or the rank ordering of the pupils' achievement levels.

There would appear to be evidence from the findings of the study discussed so far for cautious optimism with regard to gender issues relating to pre-service teachers and their assessments of pupil capabilities and potential. However, it would be somewhat premature, and not sufficiently supported by research, to conclude that all is now well in regard to these issues.

There are a number of factors which may explain why the data did not reveal statistically significant results. The instruments used may not have been sensitive enough to detect statistically significant differences in the pre-service teachers' perceptions of pupil capabilities and potential; no data were collected to determine the pre-service teachers' views on gender-stereotyping which would have served to re-inforce findings one way or the other. Perhaps, too, the extent of changes in societal attitudes towards women in science among this group of pre-service teachers is more marked than was assumed and is being reflected in the results obtained.

A closer examination of the data did reveal some trends, although weak, in gender-stereotypic directions which have been found in previous related work and which lend further support to these earlier findings. These trends are of concern and some other, more general, worrying trends were also in evidence.

Further explorations of the data

When the mean scores across all the six pupils were compared by ascribed pupil gender, they were found to follow gender-stereotypic expectations (Table 1). Males scored higher on the practical report, the end-of-unit test and on potential to pursue science. Females scored higher only on the written response questions, but the mean score differences were small. These data invite further investigation.

TABLE 1.

MEAN SCORES BY WORK SAMPLE TYPE ACROSS ALL PUPILS BY ASCRIBED PUPIL GENDER AND PRE-SERVICE TEACHER GENDER.

Ascribed pupil gender	All			Male			Female		
Pre-service teacher gender	All	M	F	All	M	F	All	M	F
Work Sample 1 (written response)	6.65	6.66	6.63	6.55	6.42	6.73	6.75	6.90	6.53
Work Sample 2 (practical report)	28.37	28.81	27.68	28.67	28.69	28.63	28.08	28.92	26.73
Work Sample 3 (test)	13.42	13.33	13.56	13.58	13.24	14.13	13.26	13.43	12.98
Potential in science	20.55	20.29	20.97	20.97	20.65	21.50	20.13	19.94	20.44

When both pre-service teacher gender and ascribed pupil gender were considered it was interesting to note that when ascribed pupil gender was male, female pre-service teachers assigned the higher mean scores in all categories except the practical report.

On the other hand, when the ascribed pupil gender was female, male pre-service teachers assigned higher mean scores except to potential in science (See Table 1). Crossman (1987) also found that female teachers are more biased towards males than are male teachers. These data could be interpreted as suggesting cross-gender encouragement or that the pre-service teachers have higher expectations of same gender pupils.

When the data for the top and bottom ranked pupils were compared by ascribed pupil gender, the biggest difference in means occurred for the written response for the best performing pupil (7.67 when female, 6.85 when male). This might be interpreted as supporting the gender-stereotypic expectation of verbal superiority of females.

Pearson correlations were found across all work samples, potential in science and pupil rank by ascribed pupil gender and also by pre-service teacher gender (Table 2). The results obtained have some worrying aspects as regards the value placed on the range of assessment tools and the relationship to perceived ability and potential of pupils.

TABLE 2.

PEARSON CORRELATIONS AMONG THE THREE WORK SAMPLES (WS$_1$ (WRITTEN RESPONSE), WS$_2$ (PRACTICAL REPORT), WS$_3$ (TEST)), POTENTIAL IN SCIENCE (PS) AND PUPIL RANK (PR) BY ASCRIBED PUPIL GENDER AND PRE-SERVICE TEACHER GENDER

	WS$_2$		WS$_3$		PS		PR	
Ascribed pupil gender (Pre-service teacher gender)	M (M)	F (F)	M (M)	F (F)	M (M)	F (F)	M (M)	F (F)
WS$_1$	.56 (.51)	.50 (.55)	.24 (.20)	.28 (.34)	.35 (.40)	.43 (.35)	.35 (.38)	.32 (.27)
WS$_2$			.48 (.40)	.41 (.53)	.48 (.50)	.54 (.54)	.62 (.55)	.43 (.49)
WS$_3$					.74 (.75)	.70 (.67)	.80 (.81)	.91 (.93)
PS							.72 (.79)	.75 (.66)

The highest correlation for both male and female pupils was between the end-of-unit test and pupil rank; that is, test performance was the best predictor of pupil rank. Also, the correlation was higher for female pupils than for male pupils. When pre-service teacher gender was considered, again the highest correlation was between the end-of-unit test and pupil rank with female pre-service teachers correlating more highly than male pre-service teachers. These results could be interpreted as meaning that test performance is regarded as a better predictor of relative pupil performance for female pupils and that female pre-service teachers put more stock on test performance as a predictor of relative pupil performance. Correlations were also very high between both the end-of-unit test and potential in science and between pupil rank and potential in science in both cases. Male pre-service teachers, however, had higher correlations than female pre-service teachers which may indicate that they place higher emphasis on test performance as a predictor of potential.

In general, test performance would appear to have been perceived as the best predictor of potential in science for pupils of either gender by teachers of both genders; more so than performance on other assessment tasks. These findings have implications in relation to the changes in assessment procedures accompanying the new VCE in Victoria. If, as the correlational findings suggest, pre-service teachers persist in regarding tests as the best predictors of ability and potential in science, threats to the successful implementation of alternative assessment tools and the related benefits to pupils are implied.

CONCLUSION

This study was conducted in only one institution in Australia. It would therefore be premature to conclude that the genders of pupils or pre-service teachers are not factors affecting assessment of pupil work. Despite the lack of statistical support for this contention by the findings in this study, the weak trends along gender-stereotypic lines that were found invite further research.

For teacher training courses, this study would suggest that gender issues in education generally, and in science education specifically, should receive higher priority in order to attempt to redress even the weak trends revealed.

The implications of the correlational findings relating to dependence on tests as predictors of pupil achievement and potential in science also need addressing if the introduction of alternative assessment tools is to succeed.

The pre-service teachers involved in this study live in a society where, at least in legislation, equality of the sexes is recognised. Also, they had undertaken their teacher-training in an institution which brings gender issues in education to their attention even if gender inclusiveness is not totally integrated and practised in their course. The future with regard to gender factors in the assessment of pupil work might be viewed with guarded optimism; this is indicated by the lack of statistical support for gender differences in assessment found in this study and only the weak trends identified along gender-stereotypic lines. This is not to say, however, that gender issues relating to science education per se have been successfully addressed, nor that the issue relating to assessment is a dead one.

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SCIENCE AND REPORT WRITING

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ABSTRACT

In recent years Australian primary schools have adopted an across-the-curriculum approach to writing. However, relatively little research has been conducted in the area of primary science. This paper reports the result of a small scale collaborative study involving a Year 2 and a Year 5 class, and their classroom teacher, which used science activities as the basis for developing report-writing skills using a framework consisting of three focus questions. Students in both classes learned to use the framework in one term and it was found that it improved the quality of reports.

INTRODUCTION

Barnes (1969) claimed that the understanding of learners is reflected in their writing. Considering this importance it is surprising that writing has received minimal attention in the field of primary science (Francis & Hill, 1990).

Tunnicliffe (1988) outlined a scheme for developing students' skills in writing reports in primary school science. She used a series of outline shapes as a means of reminding children what to write. Each shape represented a stage in the logical sequence of a report such as "What I did", "What did happen?" and "What I found out". Hill and Skamp (1990) incorporated the Tunnicliffe approach in an account of the way in which primary science can be used as a vehicle for developing writing skills. They suggested a number of focus questions to which students might respond when writing a report. These included

- What do we need to find out?
- How could we find out?
- What will we do?
- What was done?
- What happened?
- What did we find out?

This was the starting point for this study which investigated the outcome of using a combination of shape code and focus question. The three questions and associated shape codes used were

1. What did I do? ▭
2. What happened? □
3. What did I find out? ○

THE INVESTIGATION

The authors and the classroom teachers of a year 2 and year 5 class were involved in this study. There were 29 and 28 students respectively in the classes at a primary school with an enrolment of 550 pupils from predominantly middle class families.

Students averaged one science lesson each week, taken by the teacher given responsibility for science. The school had a strong literacy program with an emphasis on narrative writing.

During the investigation the authors were responsible for eight additional science sessions spread out across the term. These sessions were activity-based and problem-oriented and organised in the manner advocated by Charlesworth and Lind (1990). The questions investigated are listed below.

Week	Investigation
1	What can we do to make Aspro Clear tablets disappear faster when placed in water?
2	What properties can be used to describe, identify and group liquids?
3	How do pourable solids behave?
4	How and why do we change the properties of things?
5	What properties can be used to describe, identify and group odours?
6	How do ball bearings behave when they roll?
7	How do magnets behave?
8	How can a balloon be used to move a message a distance of more than 10 metres?

The intent of this series of investigations was to assist children to move from a situation in which there was a number of loosely structured activities to one which is more open-ended and in which they have greater control.

In the first week of the study the children were asked to write about their initial investigation before the report-writing framework was introduced.

In week 2 the teachers introduced the shape code and focus question framework and the children used records they had made during the activity to write a report later in the day in which the investigations were carried out. Large cardboard shapes with the focus questions on them were prominently displayed around both classrooms at this time. The students found that these were a useful reminder of how to structure a report, particularly in weeks two, three and four.

Initially the children wrote rough reports as they progressed through the activities and later wrote them up on the prepared sheets which used the shapes as a place to write answers to the framework questions. The shapes were particularly useful for Year 2 students who found it of value to link the shapes with questions - they continually related the two to assist the sequence. In subsequent weeks the students began to use the framework for organising their own records as well as their final reports. These reports were discussed in class and displayed in the classroom. In later weeks, particularly in Year 5, more students began to use the prepared sheets to write their reports as they worked. Some of the Year 5 students towards the end did not even use the sheets but had internalised the framework and wrote their reports onto their own paper. The teachers reported that some students used the framework to write reports in other areas of the curriculum.

It was predicted that this practice in the use of the framework would result in an increase in the proportion of appropriate statements in response to the three focus questions as follows -

- procedural statements for question 1;
- observations and comparison statements for question 2; and
- conclusion statements for question 3.

RESULTS

Table 1 reports the mean and standard deviation for the number of words in reports of the year 2 and year 5 class over the 8 weeks. The results in table 1 show that practice in using the framework increased the average number of words per report for year 2 but had the opposite effect for year 5. For year 2 the framework provided a guide for the kind of things that should be reported. For year 5 it provided a means of deciding whether something should be eliminated. For example, after week 3 few year 5 students continued to report who distributed and collected materials.

TABLE 1
MEAN AND STANDARD DEVIATION FOR THE NUMBER OF WORDS PER REPORT EACH WEEK FOR EACH STUDENT GROUP

Week	Year 2		Year 5	
	Mean	SD	Mean	SD
1	*		178.8	80.9
2	29.3	11.0	170.3	87.7
3	56.4	17.5	107.1	66.2
4	67.7	28.0	88.3	48.0
5	49.3	16.9	66.4	21.3
6	64.1	27.5	-	-
7	56.8	43.4	47.8	20.8
8	88.1	29.1	74.2	28.1

* Not able to be coded - mixtures of diagrams, squiggles, part words, single words and short phrases.

The children's reports were analysed each week in terms of the number of statements made, the type of statement, style and content. No account was taken of grammar and spelling. It should be noted that the reports reflected what they did and were thus influenced by the nature of the particular investigations.

Table 2 shows the average number of statements, by type, for year 2 and year 5 students each week. O statements represent observations, P statements describe procedures, D statements are conclusions and the E category includes all other statements.

TABLE 2
AVERAGE NUMBER OF STATEMENTS, BY TYPE, PER REPORT BY WEEK FOR YEAR 2 AND YEAR 5 STUDENTS

Statement	1		2		3		4		5		6		7		8	
Type	Yr 2*	Yr 5	Yr 2	Yr 5	Yr 2	Yr 5	Yr 2	Yr 5	Yr 2	Yr 5	Yr 2	Yr 5 **	Yr 2	Yr 5	Yr 2	Yr 5
P	-	7.2	2.9	5.7	2.9	5.0	2.7	5.7	4.0	4.3	2.9	-	1.8	2.2	4.1	4.2
O	-	9.2	3.2	11.0	4.3	7.5	9.1	9.3	3.4	4.7	3.9	-	4.1	2.0	2.8	1.5
D	-	0.1	0.0	1.3	0.2	0.7	0.3	0.8	0.3	1.0	0.1	-	0.5	0.7	0.5	0.7
E	-	2.2	0.2	1.3	0.3	1.0	0.0	0.3	0.1	0.0	0.1	-	0.0	0.0	0.8	0.2

* Year 2 students were not used to writing up science activities themselves and did not know how to start. Only three students managed to write more than two lines.

** Class not available this week.

These data in table 2 show that a considerable change occurred over the period of the study. These changes included

- a reduction in the number of other (E) statements;

- an increase in the number of statements of conclusion (D). This increase was almost immediate for year 5 students but gradual for year 2. This is probably the most significant change in the students' writing. The investigations took on a purpose and the students began to draw inferences and conclusions from the outcomes of the activities; and

- some reduction in the average number of procedural and observational statements in weeks 5-8 compared with weeks 1-4. These statements became more more concise and inclusive. The changes also reflected differences in the nature of the investigation and the degree of student control.

TABLE 3
AVERAGE PERCENTAGE OF STATEMENTS IN EACH OF FIVE CATEGORIES BY FOCUS QUESTION FOR STUDENTS IN YEARS 2 AND 5 FOR WEEKS 2 AND 3 AND WEEKS 7 AND 8

Statements and question type	Average percentage of statements			
	Weeks 2 and 3		Weeks 7 and 8	
	Year 2	Year 5	Year 2	Year 5
P1	72.5	68.2	79.7	87.2
O1	25.2	18.9	13.0	10.1
C1	2.3	1.2	4.2	1.3
D1	0.0	0.0	0.6	1.3
E1	0.0	11.7	2.4	0.0
P2	15.4	25.0	16.7	44.9
O2	64.6	63.5	23.4	30.2
C2	14.0	6.7	39.0	19.5
D2	2.6	0.7	2.0	2.0
E2	3.4	4.3	18.9	3.4
P3	15.6	0.0	2.9	0.0
O3	40.6	44.9	41.2	2.5
C3	28.9	13.6	20.4	14.2
D3	4.6	41.5	32.7	83.2
E3	10.4	0.0	2.9	0.0

Type of statement

P	Procedures
O	Observations
C	Comparisons
D	Conclusions
E	Other

Focus Questions

1. What did I do?
2. What happened?
3. What did I find out?

Table 3 reports the percentage of statements in each of five categories by focus question for students in years 2 and 5 for weeks 2/3 and weeks 7/8, the beginning and the end of the intervention. These data generally support the predicted trends. Both the percentage of procedural statements and conclusions increased in response to focus question 1 and 3 respectively. However, there was a decrease in the percentage of observations and comparisons in response to focus question 2. The latter can be explained by the reduction in the number of separate parts to the investigation as the term progressed. It appears that the students did develop the capacity to write appropriate kinds of statements in response to the three focus questions as further evidenced by the annotated reports which follow.

Rebecca (year 5)

Week 1 - a good example of the narrative style used by most students at the beginning of the study.

> First Mr Frances gave us 2 beakers and an asprin tablet. We had to fill 1 beaker up with cold water and we droped the asprin in the water. We watched the asprin dissolve. First it floated to the top and there was lots of bubbles on the bootum. It then moved to the side and lots of fluffy stuff came to the top. It broke in half and started to dissapear.
>
> We then had to predict what would happen if the aspren went in hot water. We then filled the beakers up 1 hot, 1 cold and Mr Frances gave us two more asprins. At exactly the same time we had to see if the tablets dissolved faster in hot water or cold water. It dissolved faster in hot water.
>
> We then wrote down all the different ways the tablet could dissolve faster. We then had to try one of the ways out. We tried cutting it up and putting it in hot water and it went faster.

(This report ends with a description of a competition students devised to investigate the outcome of a number of such variables in combination.)

Week 2 Rebecca was one of the first students to successfully use the framework to organise her report. Note the reduction in category E statements.

1. What did I do? Mr Francis put 3 test tubes out for us to work with. He said we had to use our eyes and record what we saw. Then we smelt them and recorded what we smelt. Then we poured them into a Petrie dish and felt them.

2. What happened? This is what I recorded.
    - A. is a goldern brown colour It's not transparent when shaken bubbles appear. It smells yuck It feels oily
    - B. is transparent. When shaken it fizzers. It looks like vinigar and smells sour.
    - C. is transparent. When shaken it gets thicker and bubbles move slowly to the top. It smells sour.

D. is not transparent it dosen't shake It looks like goldern syrp It smells sweet.

E. is transparent when shaken bubbles rise to the top. It smells plane it might be asprin

F. is not transparent when shaken bubbles go to the top it looks likes water it smells plain.

G. is transparent. When shaken bubbles go to the top water smells plain.

H. is transparent When shaken bubbles go everywhere. It's clear yellow it smells plain.

3. What have I found out? I found out that you can't tell what something is if you just look at it. Sometimes you have to smell, feel and touch to know.

Jonathon (year 5)

Week 1 Jonathon's report is set out in sections which, superficially, resemble the format used in previous science lessons. He is representative of the minority who tried to follow the pattern used by the teacher responsible for science.

There was a lot of bubles.
It smelt horrible
It looks like whate polotion
It sounds cracklg

When we put the tablet in the hot water the tablet stayed on the top it smelt like lemon really strong the bubbles were bigger than the cold and there were heaps of them. It looked like that when it was disolving. The hot was 97 seconds faster than the cold.

Hot	Cold
Stays on the top	Bubbles stayed
makes it go very fast	

Week 5 This report shows some progress in the use of the framework. This report contains more detailed observations than week 1.

1. What did I do? We observed what we saw and wrote it down also we were given a piece of toast a piece of bread a container of cream and a container of milk.

2. What happened?
first we observed the differences between some bread and some toast the bread was white, fluffy, soft, it bent, it was moist, the crust was brown and the bread was a high as the crust. The toast was brown, The crust was brown, it was white inside and brown on the outside. it was hard, it was thinner than the bread except the crust, it didn't bend and it was dry also we got some cream and wrote down what it was like, it was thick, white, runny, it stuck onto

the side of the jar then we shock the jar with the cream in side and then we wrote down what it was like then it was yellow, a big lump and sort of water around the lump, it wasn't runny except the stuff that was around the yellow lump and the yellow lump was butter also we got some milk and wrote down what happened it was white, runny. it didn't stick to the jar much, it was wartery then we shock the milk and then we wrote down what we saw a little bit stuck to the side, it was thicker than before, it didn't smell and the bits that stuck to the side were lumpy also we added vinger.

3. What have I found out?
I found out that if you shack cream in a jar you can make butter also I found out that power alters things.

Week 8 Jonathon seemed very interested in this open-ended task. His group tried to develop an arrangement which would move a message in either direction. The report was written as the activity proceeded, and indicated an internalisation of the framework in that the shapes and questions were no longer part of the report.

We got some string and tied it to some objects the distance was about 7 metres. we put a straw around the string and put a ballon onto the straw. we stuck it on there and we blew it up and let it go.

The ballon pushed the straw down the piece of string. air preacure pushed the ballon down. It depended on how heavey the weight was. it took 2 seconds to travel 7 metres with no weight but if it had a weight on it it would go slower.

I found out that you need to ballons on it one facing one way and the other facing the other way for it to get there and back.

Alicia (year 2)

Week 1 Alicia organised her report in separate episodes. She provided a good account of what she observed.

it sunk to the bottem strait away and it fizzed up now thear is fizz evrywer in the cup it smells very nice how it has deasolved. it will sink to the bottem agein and it will rise as it gets smaller

When i put it in the cup it fizzed up a lot farster then the oun in the cold watter. but the oun with the cold watter

I put the taplet in and even thow it was broken up it sended the fizz all arond the cup then it risded to the top and deasolved

Week 5 Alicia's final report is complete with diagram. Her account is not only descriptive but also indicates that she had made sense of what happened.

1. What did I do?
   I Blyndfoled my Patna. I gave Amanda a gumleaf. And she had had to try and find out what is was by touch and smell.

2. What happened?
   When I smelt them I did not know what they wher straigt away. Mr fracers put one over in a spot and it had a name on it. And then we had to smell And find wich one was the same.

3. What have I found out?
   vics is made out of gumleavs That if you smell things you'r nose will tell you what it is.

Geoffrey (year 2)

Week 1 Geoffrey found it difficult to know what to write.

When it is in hot water it desovld faster
string gos to seconds faster

Week 6 His report indicates that he is able to use the framework to develop a coherent account of what he did, what happened and what he made of these observations.

1. What did I do?
   We rold the Big ballberings and little ballbering too.

2. What happened?
   the ballberings made Dots on the paper

3. What did I find out?
   I have fond out the fast Balls had a longer gap (between dots) than the slow balls

(Geoffrey went on to use diagrams in his later reports to supplement his brief text)

The above reports also illustrate some gender differences. Initially girls were better at report writing than boys in terms of the number of words they wrote and in their general standard of writing. Boys tended to have greater initial confidence in the science investigations. However, during the term girls gained in confidence in science and improved their reporting skills relative to boys in terms of the use of the framework thus increasing the initial gap. The classroom teachers also noted that some children who were not good at 'creative' writing proved to be competent reporters in the science context. These matters deserve further investigation.

CONCLUSION

Both the year 2 and year 5 classes responded well to the use of the framework. By the end of the term almost every student could successfully structure a report in terms of the three focus questions. While these questions gave direction to their reports they did not seem to restrict what the children wrote or reduce the diversity of what was written.

In primary science there has been a lot of hands-on work, but to move from hands-on to minds-on has not always been achieved. The relatively simple framework used in this study became easily internalised by most students. Once this occurred students were able to

- not only describe hands on activities but begin to interpret the outcomes of those activities.
- convert their observations and interpretations into a report.
- move from narrative writing to another genre.

As investigations become more open ended and students, begin to take control then questions such as, 'How can we find out?', could be added to the framework. Further collaborative research is needed to develop a revised report-writing framework which has wider application across the primary school curriculum.

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HISTORY OF SCIENCE, INDIVIDUAL DEVELOPMENT AND SCIENCE TEACHING

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ABSTRACT

The existence of similarities between the ideas of modern students and those of early scientists have led to suggestions about how the history of science can be used to help students undergo similar transitions to those experienced by early generations of scientists. In this paper attention is focused not only on these similarities but also on some crucial differences between the processes and concepts or conceptual frameworks of these two groups of people. In the light of these similarities and differences some of the implications for producing and using historical material in the science classroom are discussed.

INTRODUCTION

Over the last three or four years there has been a dramatic increase in the number of publications which extol the value of using the history of science in the teaching of science. A number of people have indicated that there are striking similarities between the development of modern day children's ideas about everyday phenomena and those of scientists throughout history. It has been suggested that these similarities make an appeal to the history of science an eminently suitable means of helping students to progress towards more scientifically acceptable notions than the ones with which they initially enter the classroom (Matthews, 1989; Sequeira & Leite, 1990). In this area a number of claims are made which require closer scrutiny before they can reasonably be allowed to influence classroom practice in a substantial way. Firstly, there is the overall claim that the similarities do indeed exist; secondly, claims are made about the source of these similarities; and, finally, there are claims which relate to implications which these similarities have for teaching science.

THE EXISTENCE OF SIMILARITIES

Processes

In a previous paper (Gauld, 1988) the widespread occurrence of the 'pupil-as-scientist' metaphor was discussed and it was argued that this metaphor embodied the notion that there is a real sense in which children seek to understand their world and construct explanatory schemes in much the same way that scientists do. This notion has found currency with science educators (Driver, 1983), developmental psychologists (Carey, 1985b; Karmilhoff-Smith & Inhelder, 1975), philosophers of science (Kitcher, 1988) and historians of science (Nersessian, 1989).

While it may be true that, at one level, such similarities can be discerned between the cognitive functioning of children and scientists the extent of the similarities is not at all clear. One could argue that the unconscious development of the ideas of the child is a substantially different process to the largely conscious theory construction of the scientist who is (and has to be) aware of the data which require explanation, the ideas of others, the problems with each alternative proposal and so on.

A second substantial difference is that children's ideas are developed privately while scientific ideas, in order to be scientific, must eventually be developed in consultation and confrontation with the views of other scientists working in the same or similar field. Because of this the ideas children develop will always commence from much the same beginning in everyday experience while those of scientists (at least in the public arena) will begin from the current scientific knowledge and so will tend to be cumulative.

Concepts and conceptual structures

Wandersee (1985) in the area of plant nutrition and Sequeira and Leite (1991) in the area of force and motion provide lists of propositions from students (expressed in single sentences) alongside lists of similar propositions held by scientists who lived in earlier times. Although the language is sometimes different the parallels between the associated lists are striking but again questions about the extent of the similarities must be asked. Are the similarities isolated or are the propositions located in frameworks which themselves are similar? Do the propositions contain concepts with similar meaning to both the students and the earlier scientists? These questions have been explored by Carey (1985a), Clement (1983), McCloskey (1983), Nersessian and Resnick (1989), Robin and Ohlsson (1989), and Wiser (Wiser, 1988; Wiser & Carey, 1983). Nersessian and Resnick (1989) demonstrate clearly that, in some cases at least, the similarities extend beyond the propositions themselves to the conceptual structures in which they are embedded.

However, there are also significant differences which are not obvious in such analyses as these. The conceptual structure described for students may be closer to exhausting all that can be said about the extent of their framework while, for scientists, much finer detail has been deliberately ignored in making this comparison. For example, there was a great deal of elaboration - both verbal and mathematical - in 14th century theories of motion (Dijksterhuis, 1961, pp. 172 - 209) which goes far beyond the bare bones presented by Nersessian and Resnick and which would find no parallel at all in the frameworks of modern-day students. As with the point made above on processes, the ideas of the early scientists were developed consciously and through interaction with the ideas of others while modern day children may never have been aware of their ideas until questioned by the researcher.

An issue debated in the literature relates to the coherence of the framework of concepts related to a particular topic area. Some people (e.g. di Sessa, 1982) believe that intuitive knowledge about, for example, force and motion, exists as units appropriate for specific phenomena but largely unconnected with units appropriate for responding to other phenomena. On the other hand Nersessian and Resnick (1989) believe that these units are connected so as to form an integrated whole which functions to determine responses to a whole range of phenomena. Of course, the second of these alternatives would be closer to the scientific position than the first.

Sequences of concepts or conceptual structures

While the claim that modern day students and early scientists possess similar concepts or conceptual structures is a striking one even more remarkable is the claim that, in the area of force and motion, the sequence of concepts or conceptual structures through which students pass during their first decade or two of life parallels that in the history of science from about 500 B.C. to 1400 A.D. The most detailed comparison was carried out by Piaget and Garcia (1989, pp. 30-87) who traced the parallel with early ideas such as those of Aristotle through the views of Philoponus to the impetus notions of the medieval scientists.

Such a parallel (if it does indeed exist) provides an example in the cognitive context of the now largely discarded maxim 'ontogeny recapitulates phylogeny' in the biological context. Just as it was once believed that the embryos of the higher organisms passed through phases where they displayed in order characteristics of their evolutionary precursors so the developing ideas of children are seen as passing through phases which reflect in order the development of these ideas in history.

While evidence for such parallels of sequence is scant there are again good reasons for asking whether differences like those referred to in the previous section are sufficient to diminish the significance of the similarities. Not only are differences in the concepts themselves to be expected, but one could argue that the details of the way concepts and conceptual structures change would also be different. Again, for modern students, the change generally occurs unconsciously without any awareness of cognitive mechanisms or verbally expressed reasons and without conscious reference to confirmatory or contradictory evidence, while for scientists it is these that are used to control or rationalise the changes which take place.

EXPLANATIONS FOR THE SIMILARITIES

Processes

If one ignores the specific content of knowledge and broadly conceptualises the change of knowledge as a result of the pressure due to discrepancies between expectations (whether conscious or not) and perceptions or conceptions, the same model can be used to understand the changing cognitions of a baby, young child, adult or scientist. It is a model used to describe the way animal behaviour becomes adapted to the context in which the animal lives.

> Cognitive processes seem, then, to be at one and the same time the outcome of organic autoregulation, reflecting its essential mechanisms, and the most highly differentiated organs of this regulation at the core of interactions with the environment (Piaget, 1971, p.26).

This model as elaborated by Piaget applies to cognitive change at the unconscious level, from unconscious to conscious thought (conceptualisation or 'thematisation'), and within conscious thought itself.

Concepts or conceptual structures

Similarities in concepts or conceptual structures (see for example, Wandersee, 1985 or Sequeiro & Leite, 1991), in so far as they exist at all, are more difficult to understand. The contexts in which they are developed are so different it is not easy to find a satisfactory explanation for why concepts should be so similar. Those that have been proposed are based on much unsupported conjecture.

As has been pointed out above, children's notions are developed relatively rapidly without a great deal of conscious control whereas those of early scientists developed very slowly through detailed analysis and consideration of implications of a variety of alternative proposals with a greater amount of information to be taken into account. Differences in the material environment of the two are substantial with modern artefacts and TV programmes providing examples of phenomena (such as radio and space flight) unavailable to earlier generations. The social environment of the modern child is likely to be founded on vastly different presuppositions about the world than that of the ancient Greek, medieval or 17th century scientist. One would expect the meaning of children's explanations to reflect, to some extent at least, the presuppositions of the culture into which they were born.

The type of comparison where differences in social context, role of prior notions, motivation or level of awareness of ideas might lose their force is that between the very young child and people living very early in the history of civilisation. For both ot these the effect of the social environment on conceptual development may not be so great and the direct interaction with the world of objects may play a more dominant role. If early childhood experience with objects is much the same at all historical periods the emergence in the theoretical thought of early scientists of notions which previously and unconsciously guided their actions (and those of young people today) is not a surprising one (see Piaget & Garcia, 1989).

A small scale example of this situation is provided by an experiment carried out by Piaget and his colleagues (Piaget, 1977). Children were asked to project a ball (whirled on the end of a string in a horizontal circle around the head) into a target. In performing this task even the younger children quickly discarded a common but unsuccessful strategy and developed a successful procedure. However, when asked what they had done to project the ball into the target, many of those who had succeeded described the unsuccessful strategy! Conscious awareness of the successful procedure did not occur until a number of years later.

McCloskey and Kargon (1988) suggested that the influence of scientific cultural pressures is likely to be weaker in the period of scientific development labelled by Kuhn as 'pre-paradigmatic' during which there is a lack of one dominant point of view. For them both the child and the pre-paradigmatic scientist arrive at their theories in much the same way.

> because they were at the same point in theory formation, and because they began with similar construals of the problem domain, similar characterizations of the major phenomena to be explained (e.g., an object that is set in motion continues moving for some time after it is no longer in contact with the original mover, but eventually stops), and

> similar views about the form an explanation should take (i.e., explanations should refer only to mechanical factors and not to intelligence residing in inanimate objects, and so forth) (McCloskey & Kargon, 1988, p.66).

For McCloskey and Kargon the differences which do exist between the conceptions of modern children and medieval scientists depend on differences in world view, the environment of objects, and the self-consciousness of the work of the medieval scientists. These factors act as perturbations within their overall explanation.

Sequences of concepts and conceptual structures

Apart from the common cognitive processes which they identify, Piaget and Garcia's more detailed explanation for the parallels in how force and motion were understood by their modern subjects and in the history of science applies only to that situation and cannot be easily extended to other areas of science. In fact, Piaget and Garcia's concern was not to search for parallels in sequences of concepts but to identify parallels in processes (Garcia, 1983) and their explanation in the above situation refers to the two separate courses of development rather than to reasons why they should be so similar. In essence if the starting points are similar and the same processes operate then one might expect to find that the resulting sequences of concepts are similar for a time at least (see Piaget & Garcia, 1989, p. 77).

Their general position (which is analogous in broad outline to that of McCloskey and Kargon) leads them to state that 'once a discipline has constituted itself as a science, as physics did after Newton, there is of course no longer any substantive relationship between scientific and psychogenetic concepts' (Piaget & Garcia, 1989, p. 63).

Kitchener (1986) pointed out that Piaget was not so much interested in the development of individuals - whether children or scientists - but in what Piaget called 'the epistemic subject'. The epistemic subject is defined by 'what is common to all subjects at the same level of development rather than by 'what is unique to a particular individual' (Kitchener, 1986, p.154). Thus Piaget's position tends to ignore differences in the cultural context - both societal and scientific - in which individuals find themselves. For this reason one needs to be careful in drawing conclusions from the work of Piaget and Garcia for the classroom where individual differences may be more important.

USING HISTORY TO CHANGE STUDENT CONCEPTS

There has been considerable discussion of proposals for teaching strategies based on the similarities between the processes of conceptual change in scientists and students (Posner et al., 1982). Implications for teaching derived from the similarities between the concepts or conceptual structures of students and early scientists have not been so thoroughly developed.

The fact that the similarities exist at all makes the history of science a more useful candidate for helping to teach science than if this were not the case. Knowledge about conceptual change in history thus becomes a source of strategies for changing student notions into ones closer to those of contemporary science. Two important implications for successfully using history to bring about changes in student concepts follow from the above discussion.

- the first step in any procedure must surely be the articulation by the students of ideas which, up to this point, have probably been sub-conscious. In the classroom this will usually be the outcome of teacher questioning or discussion by students.

- The historical information must be adapted so that it is in an appropriate form for use in the classroom. The form of this adaptation will be guided by the beliefs which are exhibited and the language which is used in the initial discussion with the pupils so that the historical information can be linked with these beliefs.

In undertaking this adaptation, producing classroom material and developing teaching strategies a number of further issues should be taken into account.

- If students have indeed passed through a sequence of concepts to reach their present view it is likely that they will be unaware of the course of this development and may not recognise previously discarded ideas.

- Some historical data, meaningful in the experience of early scientists, might not be meaningful or accessible to modern students. For example, observational data about planetary motion (or even the nature of planetary motion itself) is not something which easily connects with the everyday experience of students today.

- Some of the arguments that were compelling for particular scientists may not be compelling for particular students today. It is probably true, for example, that many of the arguments which moved scientists on from the 'impetus' view would not be suitable for students because they are too technical.

- Most students do not possess the same motivation to work to develop their understanding that early scientists had. The painstaking and tenacious search through alternative points of view which led Darwin to the publication of his Origin of Species may not be a characteristic of many students of any period.

CONCLUSION

The fact that there are similarities between the ideas of modern day school students and early scientists leads to a clear expectationn that the history of science should be of value in helping students to change their concepts in appropriate ways. However, historical material, to be effective in the classroom, must also take into account the significant differences which exist between these ideas.

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SECONDARY SCHOOL STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENCE

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ABSTRACT

A stratified random sample of 32 secondary students chosen from nine schools in eastern and central Newfoundland, Canada, were interviewed to determine their views of the nature of science. The interview transcripts were reduced to a set of individualized conceptual inventories. A number of general trends were identified. Most students were found to have difficulty establishing the domain of science, although many tended to view the practice of science as cumulative. Although the majority of the sample asserted that scientific information was tentative and provisional, they tended to regard factual information in science to be absolute and irrefutable. Scientific theories appeared to be understood only in a naive sense in that most students regarded theories as suggested explanations for fairly discrete events as opposed to elaborate interpretive frameworks. In accordance with previously documented evidence (Aikenhead, Fleming & Ryan, 1987) many students were found to equate the term "scientific law" with the more common legal usage of the word. Finally, elements of what Nadeau and Desautels (1984) term as naive realism, blissful empiricism, credulous experimentalism and excessive rationalism were quite prevalent.

INTRODUCTION

Even a casual glance at the science education literature of the last thirty years yields the conclusion that there has been a consistent interest in the determination of students' understanding of the nature of science. Despite this, we still do not appear to have made much progress towards generally accepted conclusions. Why is this? Why have well known instruments like TOUS (Cooley & Klopfer, 1961), SPI (Welch, 1966), NOSS, (Kimball, 1965), and NSKS (Rubba & Anderson, 1978), failed to provide definitive answers? All share a characteristic which may represent a fatal flaw. All were developed from the perspective of the expert. As such, all were potentially subject to what Munby (1982) refers to as the doctrine of immaculate perception, namely that researchers tend to assume that students attach the same meaning to test item statements as do the developers of the test. The assumption that students select a particular response for the same reason as does the expert is open to question.

The view that researchers should be more concerned to identify students' own conceptions or, where they differ from those of the experts, students' misconceptions, alternative conceptions, or naive conceptions, has become widespread in the last decade. The use of open-ended interviews has become central to this work and techniques such as interviews about instances and interviews about events have become widely used. Generally, these approaches have focussed upon scientific concepts. The nature of science itself has not been a focus of interest. A recent, large scale study by

Aikenhead, Fleming and Ryan (1987) may be seen as an exception to this. However, these authors' focus on the nature of science was but one focus among many and, in any case, while students' viewpoints were widely sought in the development of the instrument, they did not serve as the starting point to the enquiry. In contrast, the research reported in the present paper is focussed upon students' own viewpoints.

Other related studies include the following: Rowell and Cawthron (1982) administered a questionnaire to 300 students and staff at several Australian universities. They concluded that science-oriented students tended to agree with a Popperian view of the nature of science, but it is difficult to know how much credence may be placed on this result in the absence of information about the validity and reliability of the instrument. Saunders (1986) asked students, professors and teachers to respond to the question "What is science?" Responses were written in essay format. No check on reliability appears to have been made, but it appeared that conceptions became more precise with time. George (1987) reports an interview with one teenager, and provides a rich account of that individual's scientistic understanding of the nature of science. The study is informative but hardly representative.

THE PRESENT STUDY

The present study was conceived as an attempt to step back, to look again at students' own conceptions expressed as freely as possible with minimum interference from the investigators. For this purpose a lightly structured interview technique was applied.

Research Questions

The following research questions were considered:

1(a)How do senior secondary school students view science in general?
  (b)How do they conceptualise change in science?
2(a)How do senior secondary school students believe scientific facts are obtained?
  (b)What is their understanding of the nature of scientific facts?
3(a)What do senior secondary school students believe about the nature of scientific theories?
  (b)What is their understanding of the function of scientific theories?
4(a)What do senior secondary students believe about the nature of scientific laws?
  (b)What is their understanding of the function of scientific laws?

Method

In the general field of research relating to interview studies of students' conceptions a variety of approaches has been used. Simpson and Arnold (1982) used note taking as their principal recording technique. An advantage of this approach is that the amount of data collected is readily manageable, but it suffers from a consequent loss of potentially important detail and completeness. The use of videotape eliminates all of these problems. Erickson (1979) and Aguirre and Erickson (1984) are among those who have adopted this approach. It is particularly useful where it is important to see students manipulating one or more objects or working out calculations, etc., but suffers from the disadvantage of providing a particularly artificial and, for some students, threatening situation.

A compromise situation is the use of audio-taped interviews. Most students have substantial experience with audio-tape recorders and are unlikely to be intimidated by them. Many investigators have chosen this as the preferred approach; it was used in the present study.

A second important question relates to the degree of structure to be imposed by the interviewer on the interview situation. Some researchers, such as Erickson (1979), leave the interview unstructured. Others, for example Arnaudin and Mintzes (1985) and Sneider and Pulos (1983), in the interest of conserving reliability, adopt a more structured style. Sometimes the interview involves asking students to arrange a set of pre-selected concepts (Champagne, Klopfer, Desena & Squires, 1981) or to respond to instances or events selected by the investigator(s) such that some represent the concept while others do not. In the present case, given the global nature of the concept involved, the decision was made to impose as little structure as possible and to attempt to encourage students to talk freely about selected aspects of the nature of science.

Sample

Free response interview studies typically face the problem of being manageable only with relatively small samples. Hence they are open to the charge that their findings are unrepresentative of the larger population. We attempted to minimise this problem by careful selection of a moderately sized sample. 32 students were selected randomly from four groups in the senior class in their respective secondary schools. Sixteen had academic averages above 75%. Eight of these were taking at least two science courses designed for university entrance. Sixteen had academic averages below 75%. Eight of these were taking at least two science courses designed for university entrance. The sample was representative in terms of school size and location. Nine schools were involved. Students' ages ranged from 17 to 20 years, with a mean of 17.6 years.

Procedure

The first step in the study was to create an appropriate interview guide. A set of questions was developed under the broad headings 'general nature of science', 'nature of scientific facts', 'nature of scientific theories' and 'nature of scientific laws'. These questions were examined by several science education experts and revised accordingly. This draft was field-tested by administration to five randomly selected high school students. The guide was revised and administered to three more randomly selected students. No further changes were deemed necessary.

The questions asked are represented at the beginning of each sub-section under the general heading results, presented below. Questions were asked in as flexible manner as possible, and were interspersed by prompts such as "tell me more about...", "what do you mean by...?," "why?", etc. Room was left for clarification wherever this was deemed necessary, both by the interviewer and each respondent. Where questions asked for a specific example of a fact, a theory or a law, respectively, those subjects who could not respond were prompted with examples.

Each subject was interviewed individually, with interviews lasting 30 to 45 minutes. All interviews were audio-tape recorded, and each was preceded by a few warm-up questions of a general nature intended to put the respondent at ease. When the interview phase was complete, each interview was transcribed. To reduce the data for analysis a conceptual inventory was constructed for each student.

Validity and Reliability

Validity and reliability were each considered from two aspects: first, with respect to preparation and administration of the instrument, and second, with respect to coding of the transcripts.

Determination of content validity of the basic question guide has already been described. To establish reliability, several questions were repeated in a slightly modified form and examined for consistency. Consistency was 100%. As a further check, a personalised questionnaire was developed for each from the student's conceptual inventory. In each case, several responses were altered in such a way as to express the opposite view originally expressed by the student. Despite this inversion, 84% of the responses indicated the original views to be maintained. Overall, we are confident that the interview process was valid and reliable.

To establish the reliability of coding of the interviews, each transcript and its corresponding conceptual inventory was examined by three independent co-operating science teachers. Each of these experts examined five transcript-inventory pairs, and was asked to identify any possible mismatches. Ninety-four percent agreement was obtained, showing good reliability for the data reduction procedure. Some minor changes were made following comments from these teachers.

RESULTS

In the space available it is not possible to describe the more than 130 views of scientific knowledge and practice which were identified. We have generally limited commentary to those views expressed by ten percent of the sample or more. This reduced the number of views by about two-thirds. Findings are presented under the four broad headings represented in the interview guide. In each case the number of views expressed did not usually equal the number of students. Some expressed more than one view in response to a particular group of questions. Others were functionally mute.

General Views

Under this heading the following questions were asked: What is science? What does doing science involve? What makes science different? How do scientists know what to do? What is a scientific method? Give an example. What is the role of observation in science? How does science change? As for each of the other groups of questions these questions were interspersed with clarifying comments and questions from interviewer and interviewee.

Few students appeared to have considered the initial question "What is science?" before, and it was difficult to obtain much clarity in their responses. However, it was possible to discern a product 'explanation' in about 60% of the answers and process oriented descriptions of science as 'studying phenomena' in about one-third. Only four students were observed to combine these two dimensions. Some apparently could not conceive of science outside of the domain of 'school science', as for example in the response "I think it involves learning some set facts and theories...and then applying them to other things." Scientists were often seen as people who..."sit in a lab all day long and do labs and study about different people and how different things come about". Science was typically seen as more rigorous than other areas of study, as "...more complex...there's more to be found out for one thing than in other subjects like literature". When asked about scientists' motivation for their work, most (about 70%) expressed the belief that curiosity and/or personal interest was most important, while about 30% believed society's needs to be a major factor. Various other motivations were suggested by more than two students. These included financial gain, ambition and the potential for application of new knowledge. In general, science was seen as a personal enterprise, and commercially funded research was largely ignored.

The question "what is a scientific method?", was not productive. Despite substantial rephrasing and probing, responses were vague. Only two responses were shared by more than two subjects, namely that "a scientific method involves experiments" (seven students) and that "a scientific method involves research" (four).

The question "What is the role of observation in science?" produced generic answers which typically had little specific application to science. The most common answer (22 students) was that scientists observe deliberately to obtain data. However, when subjects were pursued about the relationship between observation and theory, there was an almost equal split, with one side believing that observation is theory driven and the other that theories arise from observation. The following excerpts respectively illustrate this:

> ...you could watch experiments or populations or anything and you have to observe them to see if there's a difference...a marked effect by putting a certain cause in so if you can't observe it it's all speculation. You have to observe to...prove your theories.

and,

> ...you're doing some sort of experiment or whatever and you notice somethings that don't usually happen...it could be some thing important to science.

The final question in this section asked "How does science change?" While there was not substantial consensus about this, most did have a viewpoint. Eight suggested that science is continually improving itself; seven that science changes as new information is added and illuminates old; five that science changes as society changes; three that science changes as theories or concepts become more complex; and three that it changes as information becomes more specific. All of these suggest a positive image of the development of science. It was not possible to perceive any substantial tendency to refer to change in science in ways which might be related to commonly quoted philosophical or sociological interpretations of science, such as those emanating from Bacon or Popper or Kuhn or Feyerabend, etc.

The Nature of Scientific Facts

Under this heading the following questions were asked: "What is meant by a fact in science? Give me an example of a scientific fact. What makes this fact scientific? How do you think it was obtained? Are scientific facts open to question? Why?"

Almost all subjects considered it something proven. Typical responses included "Something that is proven without a doubt to be true," "Something that is scientifically proven," and "A statement that's true and always will be, I guess". Despite this almost unanimous certainty, most had difficulty giving good examples of scientific facts. For example, Darwin's theory of evolution was cited as a fact by some.

Research and experimentation was clearly the basis of determination of facts, with 21 students specifically citing this. Once established, through substantial repetition, facts were generally considered proven. The word 'proof' appeared frequently in the interviews. Paradoxically, though, when faced with the direct question "Are scientific facts open to question?" most expressed some degree of tentativeness. Seventeen explicitly stated that scientific facts are open to question. The following quote was typical of these:

> Oh there's no doubt about it they're open to question. If one scientist comes up with it and another group thought that something else was wrong or something, sure they can be proven wrong 'cause there's no precedence in science.

The most frequently provided reasons for the tentativeness of scientific facts were that either the methods used in obtaining them were flawed or that viewpoints are apt to change with social demands. Unknown interventions were also considered a factor.

Five were less sure, and considered only some facts to be open to question. Five others appeared to believe that although scientific facts are open to question, the process of questioning them is likely to be futile. Five more were quite certain that a fact is a fact and is not open to change. Overall, there appears to be an uneasy truce between a belief in the certainty of factual knowledge in science and an awareness of the tentative nature of the scientific enterprise.

The Nature of Scientific Theories

The following questions were asked? "What is meant by a theory? Give me an example. How do you know this is a theory? What is the purpose of theories in science? How are they used? What is the difference between a theory and a fact? Would it be more accurate to say that theories are models or that they describe the world as it is? Do theories ever change? How? In explaining a certain event is there such a thing as a strong as opposed to a weak theory or can there be only one theory at a particular time? Give me an example."

In general a theory was viewed as a statement of a possible but not proven explanation. For example, "Somebody has an idea about something but it hasn't been proven," or "A theory is an idea that a person has about a certain observation," or "...an educated guess." When asked to provide an example of a theory, only three students could actually respond appropriately. Where no response or no adequate response was forthcoming concrete examples were provided. When asked "What makes this a theory?" the most popular response, by 20 students, centred on lack of proof.

Most students (23) suggested that theories are models, while two suggested they could be either models or realistic explanations. Six students suggested theories to be exact descriptions of reality. Eleven of the 23 students referred to above added explanations such as that if a theory described the world as it really is it would not be a theory but a fact. Rather, "...we use them as models to help us understand the world", and, in a Popperian view "...we go by them until we find something that is more stable." In general the tentative nature of scientific theories seemed to be well accepted, even, in a Lakatosian vein to the point of tentative acceptance of multiple theories by 19 students.

The purpose of theories as explanatory devices was generally well understood as was their function in facilitating further research.

A variety of responses was obtained from the question "Do theories ever change?" Thirteen students took a naive-realist position in suggesting that theories may be proven true; that they reflect the world as it is. Six of these went further to suggest that when that happens the theory becomes a law. Nine believed that theories may change, perhaps by being disproven (five) or with the introduction of new facts (two) or new technology (two). Finally, there was a recognition of strong versus weak theories in a naive-realist sense that strong theories approximate truth better than weak theories. Generally the stronger theory was believed to replace its weaker opponent.

The Nature of Scientific Laws

Under this heading the following questions were asked: "What is meant by a scientific law? Give me an example. Why is this a law? How did it become a law? What is the difference between a law and a theory? Why do we have laws in science?"

Responses suggested much faith in the perfect truth of statements represented as laws. The word 'proof' was frequently invoked. Fifteen responses represented laws as proven facts, theories or procedures. Examples included "To me a scientific law is something which has been proven beyond a shadow of doubt," and "...a law is something that is true; that is proven. It's like a fact," and "...it's something that's really true...you can't change it." Typically, students did not distinguish between facts and laws. As well as these responses, a further ten indicated that a law is a known fact. Eight responses were somewhat different, and centred around a legalistic metaphor of laws as mandated procedures, for example "...a law is an expected thing to do, like driving within the speed limit on the highway." Typically, laws were seen to be much more certain than theories, and indeed were seen as the ultimate evolution of theories, in effect echoing what Rubba, Horner and Smith (1981) have termed the "laws are mature theories fable."

When asked "What is the difference between a law and a theory?" about two-thirds of the sample used "proof" as the basis of distinction. Examples included "The difference between laws and theories is that laws are proven facts and theories are someone's ideas which can be improved upon or changed" and "A theory is something that has not been proven but could be proven true or false. A law is something that has been proven." In response to the question "Why do we have laws in science?" the two most common suggestions were that laws provide a solid, consolidating base for science (twelve responses), and that they set directions for future research (nine responses) or guide science by defining accepted procedures (three). Once again, responses to this question focussed upon the certainty of laws and the uncertainty of theories, as for example in the response:

> If everything is theories then there is nothing that is certain. With laws we know that there are things that we don't need to improve; that we know are true. If everything was theories then there'd be no certainty.

For these students certainty and the foundation it provides appear to be the main function of laws.

Evidence of Scientistic Views

In a monograph produced as part of an extensive examination of science in Canadian schools, Nadeau and Desautels (1984) describe five separate unacceptable views of the nature of science which appear to exist in the minds of teachers and students. In this section a brief description of each of these views is presented together with evidence of their existence in the minds of the subjects in the present sample. The five views are referred to as naive realism, blissful empiricism, credulous experimentalism, blind idealism, and excessive rationalism. They are presented briefly in order of magnitude of response.

Nadeau and Desautels refer to excessive rationalism as the belief that science brings us gradually closer to the truth. In this view, science is seen as cumulative, a steadily onward march in quest of ultimate truth. Through statements such as "As time progressed more things were discovered. ...now it's pretty well been figured out," and that theories could be used "...to do further research to find out the actual truth", a total of 17 respondents demonstrated excessive rationalism.

A second view, credulous experimentalism, is described as the belief that experimentation makes possible the conclusive verification of hypotheses. In this view experimentation is seen as the ultimate arbiter of truth in science. Thirteen transcripts showed evidence of credulous experimentalism. For example, one subject stated "Newton had an idea and he wanted to figure it out so he made a prediction and tested it." Another commented "Enough experiments just proved it had to be."

The third view, naive realism, is the belief that scientific knowledge is an exact reflection of the world as it really is, and that science furnishes us with a set of facts that correctly and faithfully describe reality. Thirteen subjects, through statements such as" ... you can't argue with the way things are... there's not much room for argument" and "Science is just the study of why things happen and the way things are." and "I think [theories] are an exact way of saying what's going on," suggest a naive-realist view of scientific knowledge, a view which does not stand up well when we consider the history of science and the many changes in our theoretical and factual beliefs which occur on a continuing basis.

The remaining two views were less prevalent. One, blissful empiricism, is described by Nadeau and Desautels as the belief that all scientific knowledge arises directly and exclusively from observation of phenomena. According to this view science is seen as the relentless gathering of observational data which point singularly, objectively and conclusively to the truth. It was possible to identify such views only in six transcripts. Finally, blind idealism, the belief that scientists are completely disinterested, objective beings, was not observed at all.

Conclusion

We have presented the understandings of selected aspects of the nature of science held by a representative sample of senior secondary school students. Our general conclusions are as follows:

- Only about one-third of our sample understood that observation is theory-laden.
- The progress of science was typically seen as inexorably cumulative rather than revolutionary.
- Theoretical knowledge was seen as more tentative than that described in facts and laws.
- The 'laws are mature theories' misconception was prevalent.
- Facts and laws were typically seen as incorrigible truth, while theories were seen as tentative by definition. Once theories become laws then, by definition, they represent truth, but then they are no longer considered to be theories.
- With respect to both laws and theories, a simplistic one-to-one correspondence between explanandum and explanation was evident. To the contrary, the existence of a complex set of auxiliary assumptions which typically underlies statements of laws and theories was not acknowledged. This is not surprising given the singular hypothesis approach of school science, but it does not help students understand the way in which theories which are accepted at one point in time become unacceptable later. A one-to-one correspondence view inappropriately suggests foolishness or error as the likely explanation of the need to abandon or change an accepted theory.

It is particularly noteworthy that the above findings with the exception of the last two were qualitatively and quantitatively consistent with those reported by Aikenhead, Fleming and Ryan (1987). Hence, it appears that a global representation of students' understanding of the nature of science may be obtained by administration of the 'nature of scientific knowledge' component of their multiple-choice instrument. The triangulation provided by the findings of these two studies is encouraging.

Directions

There is perhaps a sense of deja vu about some of our findings. To mention but a few, the many writings of Armstrong, Dewey and Schwab all, in their time, espoused the case for a treatment of the heuristics of science in our science curricula. Curriculum projects such as the Nuffield curricula in Britain and American projects such as BSCS and Chem Study were developed from an enquiry orientation devised, in part, to portray the nature of science. There are many reasons for the lack of widespread acceptance of such curricula, not the least being that the view of science being presented was that of the expert rather than the learner. Today, through extensive research which has uncovered a fascinating myriad of students' alternative conceptions and misconceptions of a large number of scientific concepts, the science education community has become much more aware of the need to focus attention on students' own conceptions and work from there. A second current thrust in the science education literature is the demand for a more substantial emphasis on the interactions between science, technology and society. A fundamental aspect of this is a consideration of the nature of science itself. Unless our students understand the nature of science and its limitations they will not be in a position to properly understand its role in today's society. Unless teachers understand that they must begin by identifying where their individual students are at in their understanding of the nature of science, and learn to work from there, we will not make much progress. The 'STS' literature and the 'misconceptions' literature together offer a good springboard from which to attack this important problem.

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A SURVEY OF PRE-SERVICE PRIMARY TEACHERS' EXPERIENCES OF SCIENCE IN SCHOOLS

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ABSTRACT

In 1990, a large proportion of third year primary trainee teachers at Victoria College had observed or taught very few or no science lessons during the first two years of their course. The students felt that a lack of content knowledge, a crowded school curriculum, and problems associated with managing resources and equipment, were the main factors contributing to the low level of science being taught in schools. By the end of their third year significantly more students had taught science than after the second year. There was also a change in approach to teaching science with more practical activities being included than previously. The science method unit taught to the students in the third year of their course contributed to this increase. The students considered the hands-on activities in class to have been the most effective aspect of the unit in their preparation for the teaching of primary science.

INTRODUCTION

The Discipline Review of Teacher Education in Mathematics and Science (1989) observed that most pre-service primary teachers "have negative attitudes to science and to its teaching and learning" (DEET, 1989, p.37).

In addition to this, at Victoria College we have been, and are, concerned that "our students do not have access to a legitimate experience in the teaching of science as it is presented during the course" (Note 1). The Curriculum and Methodology (C&M) unit at Victoria College is a 44 hour compulsory third year unit. It has a very strong practical emphasis, the science being taught through a hands-on inquiry approach within a school curriculum context.

The unit, in common with most such units, has as its objectives, to

- increase students' knowledge of science curriculum and methodology
- increase students' science discipline knowledge
- create in students more positive attitudes to the teaching of science.

The main aim of such a unit is to increase the amount and quality of science taught in schools.

While there have been studies done that explore the attitudes of pre-service primary school teachers to science and the effect of methodology units on these attitudes (Skamp, 1989), there appears to be little data on the effect of such units on the amount and nature of science subsequently taught in schools.

In this study we have investigated pre-service primary teachers' experiences of science teaching during their practicum, before and after the C&M unit, and their perceptions of the usefulness of the C&M unit in effectively preparing them to teach science.

RESEARCH AIMS AND DESIGN

The four main foci of the investigation into students' experiences of science in schools were

* the amount of science experienced by students during their practicum
* the type of science experienced by the students during their practicum
* the factors the students perceived as acting against the teaching of science in schools
* the particular aspects of the C&M unit which positively changed their attitude towards the teaching of science.

These foci were chosen to see whether our concerns about the amount and type of science experienced by students were justified, and to give us better insight into why students did, or did not, teach science. The study was also intended to allow an evaluation of aspects of the C&M unit.

In 1990, all third year students (346) were required to take the C&M unit in Science. These students were the subjects of the study. Questionnaires were administered by C&M teaching staff at the end of semesters one and two. The questionnaire was administered and collected during the students' regular C&M session. The questionnaires were completed anonymously.

RESULTS AND DISCUSSION

Students' backgrounds brought to the C & M Science unit

The majority of the 346 students brought neutral (34%) or negative (51%) feelings about science to the C&M unit (Fig. 1a). In terms of their scientific knowledge, students felt that their knowledge of biological science was better than that of physical science, the knowledge of physical science being generally regarded as poor (Fig. 1b).

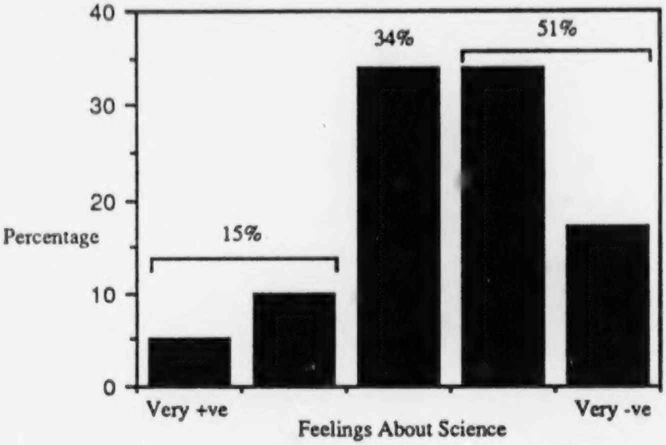

Fig. 1a Feelings about science brought to C&M science by third year pre-service primary teachers.

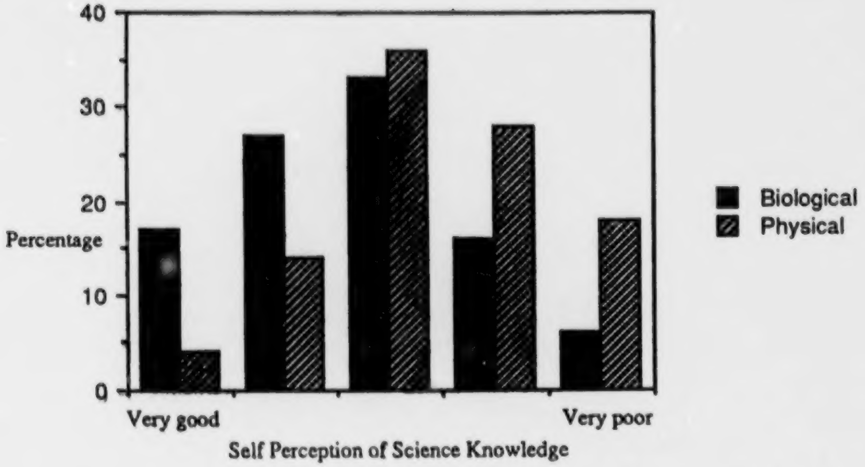

Fig. 1b Students descriptions of their physical and biological science knowledge.

Science taught in schools

The pre-service school experiences of the students surveyed were

- five weeks in first year with an emphasis on observation of practising teachers and small group teaching leading onto whole class teaching of individual lessons
- seven weeks in second year with the emphasis on increasing the amount of teaching done by the students up to half day control for at least two days
- seven weeks in third year, again increasing their teaching load, this time up to two weeks, or more, of full control.

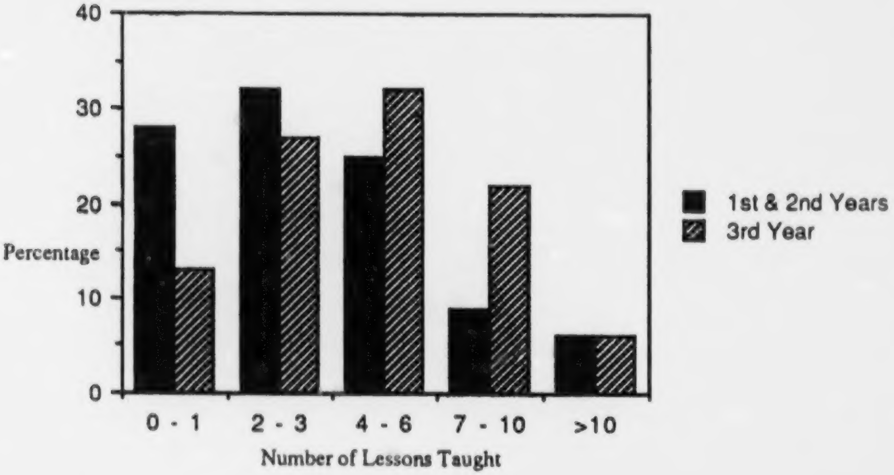

Fig. 2a The amount of science taught by students in first and second year compared to that taught in third year.

It was found that the majority of students (68%) taught very little or no science (3 lessons or less) during the first two years of their teacher training. In third year more science was taught. The number of students who had taught one or no lessons of science was halved; the number of students taking two and three lessons also decreased slightly; and the number of students taking four to ten lessons of science increased (Fig. 2a). This increase in science taught is probably not surprising as the students were taking on higher teaching loads during their practicum and also they were studying C&M Science for the first time in the course.

The total amount of science observed or taught, used as a measure of the total science experienced by the students in schools, is fairly consistent between first and second year, and third year (Fig. 2b). Again this is perhaps not surprising as the class curriculum is still largely controlled by the supervising classroom teacher. What is of concern is the small amount of science being taught in the overall curriculum, the majority of students experiencing six lessons or less, in both their first and second years and their third year, out of the 200 or so lessons they would experience during seven weeks of school practicum.

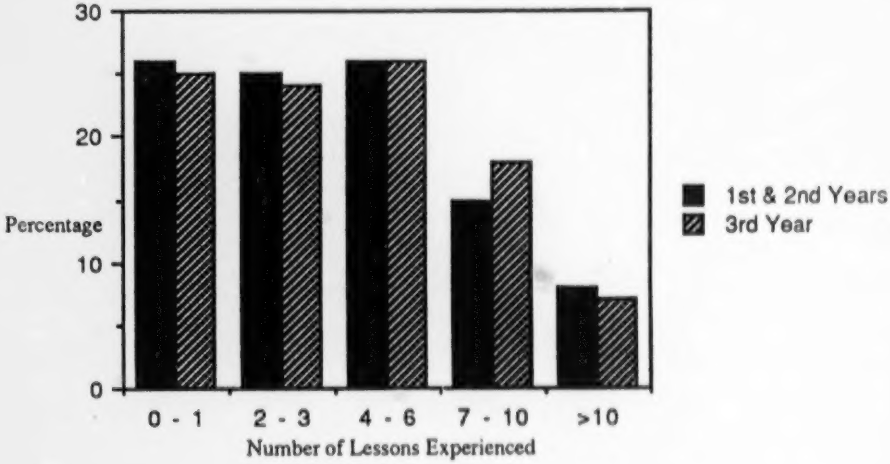

Fig. 2b The amount of science experienced in schools (observed or taught) during first and second year compared to that experienced in third year.

Research does not provide conclusive evidence as to the effect of practicum on the development of professional perspectives of students. There are conflicting views about the role of student teaching in the development of teachers, some believing that pre-service training, including student teaching, has little effect compared to the influence of pre-training experiences whilst others have argued that student teaching does have a significant impact on the development of teachers (Tabachnick and Zeichner, 1984). Whichever way one looks at it, the minor emphasis on science in the general curriculum as experienced by the pre-service teachers, and the children, is going to impact on professional teaching practice, either in the short or long term.

Table 1 shows students' experiences of the way in which science occurred within the curriculum. It most commonly occurred irregularly as a curriculum experience in its own right or integrated with social science, health, art and/or physical education. It was not common for science to be regularly taught or integrated with language and mathematics, subjects generally regarded as 'priority' subjects. This is also a cause for concern as these are two subjects with which science could be most readily integrated.

TABLE 1
STUDENTS' EXPERIENCES OF THE CONTEXT IN WHICH SCIENCE IS TAUGHT

CONTEXT	PERCENTAGE
Regularly as a curriculum experience in its own right	12
Irregularly as a curriculum experience in its own right	35
Integrated into language and/or mathematics programs	14
Integrated into social science, health, art and/or physical education	25
Not at all	13
Other	1

A final point of concern with regard to students' experiences of teaching science in schools is their perception of the amount of help they were given in their preparation to teach science. At the end of semester one, only 34% of the third year students felt that they had received help from the classroom teacher; 66% perceived they had little or no help. By the end of the year this perception was more positive with 75% feeling they had received help in preparing for teaching science lessons. However, upon further clarification it became evident that the students felt they were getting relatively little help with regard to appropriate strategies for teaching science from the classroom teacher, help coming primarily from the college (Table 2).

TABLE 2
SOURCES OF HELP GIVEN TO STUDENTS IN PREPARING SCIENCE LESSONS

TYPE OF HELP GIVEN	PERCEIVED SOURCE OF HELP(%)		
	SCHOOL	COLLEGE	NO RESPONSE
Topic information	48	47	5
Appropriate teaching strategies	28	61	11
Advice on lesson planning	37	40	23
Resource materials to find ideas	47	47	6
Preparation of equipment	46	32	22
Preparation of worksheets	32	17	51
Team teaching	26	18	56
Other	2	2	96

Comparison of the general type of topics taught in schools during first and second year compared to third year shows that in both cases biological science accounts for the majority of the science taught (Fig. 3a). In third year, more physical science was done but at the expense of other non-biological topics. The C&M Science unit at Victoria College has a strong emphasis on physical science as it is felt that this is where students lack knowledge and confidence; this perception being supported by the students self-descriptions of science knowledge. The data suggest that although the students are willing to teach more physical science in third year, probably as a result of the C&M unit, they will not easily give up that which they are more comfortable with, namely biological science. A breakdown of the first and second year data into the number of lessons taught on the different topics shows that students and teachers are more comfortable teaching biological science (Fig. 3b). This shows that as the number of lessons on a topic increased, the percentage of non-biological science taught decreased.

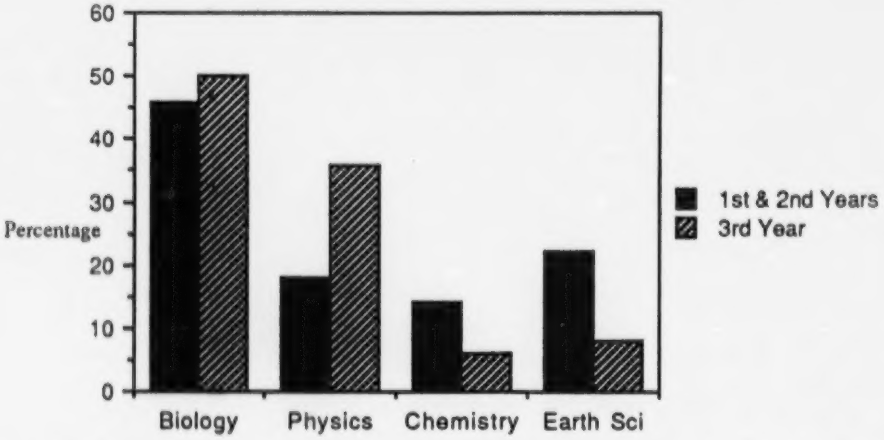

Fig. 3a Classification by general topic of the science experienced in schools in first and second year compared to third year.

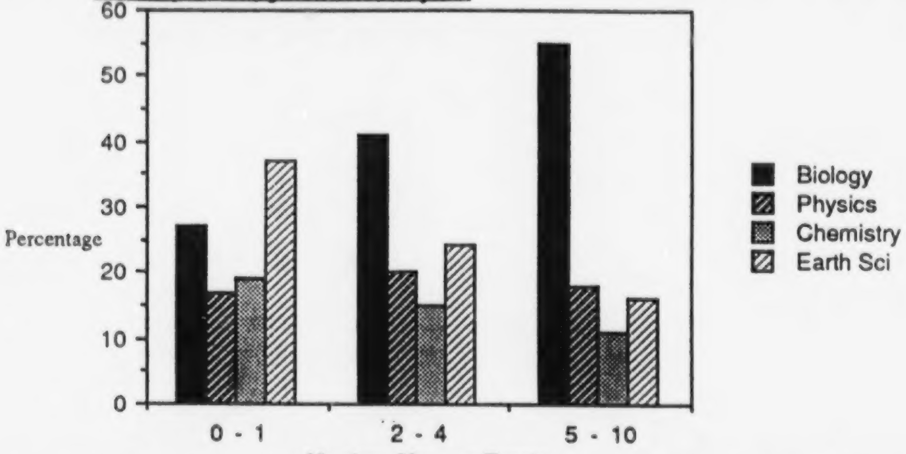

Fig. 3b Number of lessons taught in each of the science disciplines during the first and second years of the pre-service course

It was found that the amount of practical work that was undertaken in science lessons increased during third year. At the end of semester one, 65% of science lessons taught included practical work compared to 93% at the end of semester two. Within this, the lessons in the higher grades involved marginally less practical work (Table 3). Why this occurs needs to be investigated but a possible reason is lack of confidence and feeling that the higher grades would be more demanding with regard to explanations for observed phenomena than the lower grades.

TABLE 3
PERCENTAGE OF LESSONS INVOLVING PRACTICAL WORK
BY GRADE LEVEL

GRADE LEVEL	PRACTICAL WORK PERCENTAGE
Prep	100
Prep/1	100
1	100
1/2	100
2	89
2/3	100
3	86
3/4	100
4	92
4/5	92
5	83
5/6	97
6	94

The students list the three main factors acting against the teaching of science in schools, in decreasing priority, as: lack of content knowledge, a crowded curriculum, and lack of resources and problems with management of equipment (Note 2). The students did not see integrating science into language, mathematics, social science and other learning experiences as a major problem. However, that they still see the curriculum as crowded appears to suggest that they have not fully realised the potential that integrating the curriculum has for dealing with a crowded curriculum. This highlights the possibility that one way to introduce more science into the primary curriculum may be to place more emphasis on the integration of science, particularly with language and mathematics.

Student development during year three of the course

At the end of third year 75% of the students said that their attitude to teaching science had changed, this change being a positive one. A number of reasons were given for this change, the most common being that they were more confident (50%), their personal interest in science had increased (28%), they were more aware of different teaching strategies (17%), and they saw science as a good learning experience and important (16%). That an increase in confidence was regarded as the major reason for the positive change in attitude is encouraging as primary teachers lack of confidence in teaching science is generally seen as one of main reasons for the low levels of science taught in primary schools (Biddulph, Osborne & Freyberg, 1983; DEET, 1989; Yates & Goodrum, 1990).

TABLE 4
STUDENTS' PERCEPTIONS OF ASPECTS OF THE C&M UNIT WHICH EFFECTIVELY PREPARED THEM FOR TEACHING SCIENCE

CHARACTERISTIC OF C & M UNIT	PERCENTAGE
Hands-on activities in class	34
Working with small groups of children	13
Resources information	12
Integrated curriculum	10
Children's ideas about science	9
Links between science and technology	8
Your own attitudes to science	7
Current developments in primary science in Victoria	4
Personal development in science	2
Gender equity in science	1

The aspect of the C&M Science unit that the students clearly felt had most effectively prepared them for teaching science was the concentration on hands-on activities in class (Table 4). Working with small groups of children, and resource information, were the next most effective aspects, closely followed by integrated curriculum, children's ideas about science, links between science and technology, and their own attitudes, but these were markedly lower in perceived importance than hands-on activities.

CONCLUSIONS

The survey supports our previously stated concerns about the science experiences our students have in schools. In summary, the students generally seem to be

- experiencing little science
- experiencing the little science that is done as an irregular rather than regular curriculum experience
- experiencing science integrated into subjects other than mathematics and language, if it is integrated at all
- feeling that they get most help with regard to appropriate teaching strategies from college staff rather than the classroom teacher.

These data support our concerns about the effectiveness of current pre-service practicum arrangements in relation to the teaching of primary science, and the support within schools for the science teaching approaches promoted in the C&M unit.

They lend support to the idea of developing units which take more control of the students' science teaching experiences so that current approaches to, and strategies for, the teaching of primary science can be promoted with, and actually experienced by, the pre-service students. In line with this, we at Victoria College are currently trialling options which provide our students with the chance to work with children, other than in the standard teaching practicum, where they can try the various strategies presented in the unit. These options enable the students to receive support from both college staff and their peers whilst they try new techniques and strategies in the teaching of science.

This survey also supports placing a strong emphasis on the hands-on, inquiry approach, such as is done in the C&M unit, both in the actual teaching of the unit and in the strategies for teaching science presented in the unit. The students regard this as the most positive aspect of the unit in terms of preparing them to teach science. The development of the more positive attitude to teaching science reported by the students at the end of the C&M unit was probably brought about by this hands-on approach. Through actually doing the activities, the students confidence increased and their attitude to teaching science became generally more positive.

It is generally accepted that we need to try and ensure that science has a higher profile in the primary curriculum than is currently the case. Yet the approach followed in the C&M unit, that of guided inquiry, is not one that is currently embraced in our schools. In their conclusions after the first year of the PEEL project, Baird and Mitchell (1986) stated

> Teachers must experience a new technique and its consequences, before they can begin to integrate it into their repertoire...[and that] the change process for teachers attempting [these] innovations is a protracted one and requires more on-going support than is currently provided." (pp. 289 and 293)

Although this was said with respect to the development of teaching strategies which enable active learning by students, the principles could probably be transferred to the introduction of an inquiry approach to science teaching and to raising the profile of science in the primary school curriculum.

Using the C&M unit to provide students with situations where they can try out the inquiry approach to science teaching, both as students and as teachers, can give pre-service teachers an initial introduction to this teaching style. However, time constraints limit how much practical teaching experience can be gained as part of a curriculum and methodology unit.

For pre-service primary teachers to gain a reasonable amount of experience in techniques and consequences of the inquiry approach to science, the practicum experience must be used. However, how we go about this and how best to use the practicum experience as a strategy for improving the situation is a debatable point as "in many ways [teaching practicum is] an unresearched area of the preservice curriculum" (Northfield, 1988). With the current push to have more science in the primary school curriculum, the need for research into the effects of units and the teaching practicum on the development of students' professional perspectives is possibly greater now than ever before.

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PRIMARY AND SECONDARY SCHOOL STUDENTS' ATTAINMENT OF SCIENCE INVESTIGATION SKILLS

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ABSTRACT

A practical test instrument was developed to assess students' attainment of skills associated with problem analysis and planning experiments, collecting information, organising and interpreting information, and concluding. Students verbalised their thoughts as they worked on the task and their performance was videotaped for analysis. Data collected from Year 7, 10 and 12 science students illustrate the development of investigation skills and reveal important areas of student weakness.

INTRODUCTION

Woolnough and Allsop (1985) have identified three aims that can validly be achieved through laboratory work: the development of process skills and laboratory techniques; getting a feel for phenomena; and being a problem-solving scientist. Several authors have argued that scientific problem-solving skills can be developed through inquiry oriented or investigation style laboratory work that gives students opportunities to practise the skills of problem analysis and planning experiments, collecting data, and organising and interpreting data (Tamir & Lunetta, 1981; Woolnough & Allsop, 1985; Tamir 1989). Johnstone and Wham (1982) have cautioned that inquiry oriented, investigation style laboratory work is cognitively demanding and that informational inputs may overload working memory capacity. Experts cope more easily in these high information situations as they have developed automated, proceduralized routines for common processing tasks thus freeing-up working memory capacity for dealing with novel aspects of the problem, planning, monitoring and control of processing (McGaw & Lawrence, 1984; Anderson, 1985).

Experts bring extensive domain specific schema knowledge to problem-solving tasks which enables them to generate high quality problem representations which guide the selection of efficient solution processes (Chi, Feltovich & Glaser, 1981). Experts spend more time on problem analysis (Larkin, 1979), do more high level metaplanning (Hayes-Roth & Hayes-Roth, 1979), and demonstrate greater metacognitive control over processing than novices (Schoenfeld, 1986). This paper reports on a study which examines the development of science investigation skills through primary, junior high and senior high school science education.

PURPOSE AND RESEARCH QUESTIONS

The purpose of this study was to examine the problem-solving processes used by Year 7, Year 10 and Year 12 science students when conducting a laboratory-based science investigation. More specifically, the study addressed two research questions:

1. Which process skills are Year 7, Year 10 and Year 12 science students able to apply in the problem analysis and planning, data collection, data interpretation and concluding phases of a laboratory investigation?

2. What factors appear to limit students' success on practical problem-solving tasks?

METHOD

Subjects

In Western Australia Year 7 is the last year of primary school, Year 10 is the last year of junior high school, and Year 12 is the last year of senior high school. A modified random stratified sampling technique was used to select a total of 10 students from each of Years 7, 10 and 12. All students were from the top half of the population in terms of science achievement. Each sample comprised two students from each of five different schools, four students from church schools and six students from state schools, and equal numbers of males and females. The Year 12 sample comprised equal numbers of students studying either biological or physical sciences.

Procedure

The open-ended, problem-solving task was administered to subjects individually. No time limit was imposed on the students' work. Students worked on the task with concurrent verbalisation (Ericsson & Simon, 1980; Larkin & Rainard, 1984). There was minimal interruption from the experimenter except for encouragement to verbalise and for the debriefing session at the end of the task. Subjects' verbalisations and apparatus manipulations were recorded on videotape. A coding manual guided the dual and independent coding of the videotapes by two trained coders. Coding discrepancies were resolved at meetings between the coders and the investigator.

Instrument Context. The task was set in the context of engineers who design and build bridges and need to understand the factors that influence the bending of beams under load. Subjects were shown a picture of a truck passing over a bridge.

The Task. Think-aloud procedures were modelled for the subject by the investigator, and subjects practised verbalising on two arithmetic problems. The task was explained to the subject and then the subject commenced work by reading aloud the task statement presented in Figure 1.

THE TASK
Find out what factors influence the bending of beams under load

REMEMBER
I would like you to
plan and carry-out experiments,
record and interpret your results,
and state your conclusions

Fig. 1. The Task Statement

Apparatus. Figure 2 illustrates the apparatus provided for the subject at the start of the session. A wooden beam was supported by two retort stands and a load of slotted masses was suspended from the centre of the beam. A 1 m rule and a 50 cm rule lay on the bench, and a 30 cm plastic rule held vertical by a retort stand was placed next to the beam. Additional slotted masses were available on the bench. A pencil, ruler, pad and graph paper were placed to the side of the beam. The subject was shown a large opaque plastic tube which contained a range of other beams of different diameters, cross-sectional shapes and materials that the investigator would supply to the subject on request. Subjects were not permitted to examine the types of beams in the tube so they had to generate beam variables themselves rather than just cue-in to variables displayed by the selection of beams.

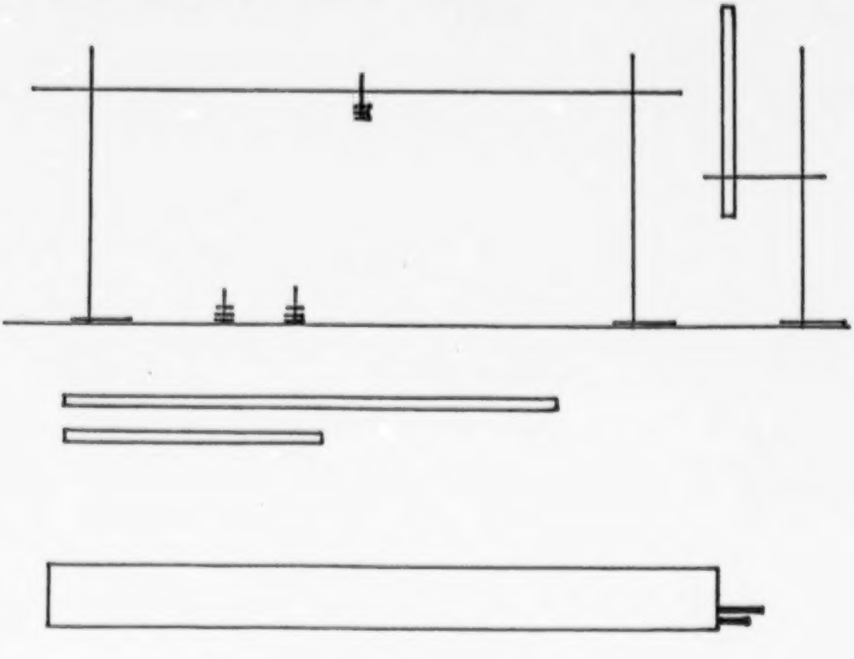

Fig. 2. Apparatus Provided for the Investigation

RESULTS

Results are presented in terms of the process skills displayed by subjects during the four phases of the investigation: (1) analysis of the problem and planning, (2) collecting information, (3) organising and interpreting information, and (4) concluding.

(1) Analysis of the Problem and Planning

One of the most distinct features of the students' problem solving was the limited amount of problem analysis and planning done before manipulating the equipment and collecting data. This is illustrated by the data presented in Table 1.

TABLE 1
STUDENT BEHAVIOURS ASSOCIATED WITH ANALYSIS OF THE PROBLEM AND PLANNING

Behaviours	Student year group		
	Year 7 (n = 10)	Year 10 (n = 10)	Year 12 (n = 10)
Number who commenced by identifying potential independent variables	3	5	7
Stated an aim or purpose for an experiment	1	3	4
Planned how a variable would be applied or measured in an experiment	0	0	6
Verbalised an intention to control variables	0	0	0
Planned data recording	0	0	2
Planned an overall approach to the investigation (metaplanning)	0	0	0

Many students commenced by identifying potential independent variables, although most independent variables (81 of 128) were identified while students were involved with experimenting. Only a small number of subjects (8 of 30) stated an aim or purpose for their experiments. Only six students, all in Year 12, planned how they would apply or measure variables in their experiments. None of the students verbalised an intention to control variables. Only two subjects planned their data recording before commencing data collection. None of the students planned an overall approach to their investigation. Inspection of Table 1 reveals a trend towards greater problem analysis and planning from Year 7 to Year 12.

(2) Collecting Information

On average the students each conducted 3.1 experiments. The number of experiments ranged from a minimum of none to a maximum of seven experiments per student. An experiment consisted of tests of a particular independent variable. There were six main independent variables that could be tested: beam length, thickness, cross-sectional shape and material; load size, and location of the load along the beam. Data regarding students' experimenting are presented in Table 2.

TABLE 2
STUDENT BEHAVIOURS ASSOCIATED WITH COLLECTING INFORMATION

Behaviours	Student year group		
	Year 7 (n = 10)	Year 10 (n = 10)	Year 12 (n = 10)
Mean number of			
Experiments performed	2.1	3.9	3.3
Measured changes in the dependent variable	4	5	6
Measured zero values for dependent variable	1/4[a]	3/5	6/6
Avoided parallax errors with measurements	1/4	4/5	6/6
Measurements made at point of maximum deflection of the beam	0/4	4/5	5/6
Controlled variables by standardising measurement procedures	0/4	4/5	6/6
Controlled variables when changing beams	1	2	5

Note. [a] One of the four students who made measurements, measured zero values.

Half of the students made no measurements of the dependent variable, they relied on qualitative comparisons of the amount of bending of different beams. Of the six Year 12 students who measured the dependent variable all measured zero values and took care to avoid parallax error. Five of the six subjects also measured beam bending at the point of maximum deflection. Most subjects collected data over a rather small range of values for the independent variables.

Control of variables could be demonstrated in three ways in this investigation. First, students could standardise their measurement procedures, for example, measuring bending in the centre of the beam, using standard loads and beam lengths when comparing different beams. All Year 12 students who measured bending standardised their measurement procedures in this way, four of the five Year 10 students who made measurements also standardised their procedures, however none of the four Year 7 students who made measurements demonstrated any awareness of the need to standardise measurement procedures. Second, subjects could demonstrate control of variables when they changed beams. For example when testing the independent variable of beam thickness, subjects could request a thicker beam of the same material and cross-sectional shape. Only eight of the 30 students demonstrated control of variables when changing beams, and as expected most of these were from Year 12. Third, students could also demonstrate control of variables when comparing the bending observed in different experiments. These data are reported in the next section.

(3) Organising and Interpreting Information

Data regarding students' organisation and interpretation of results are presented in Table 3.

TABLE 3
STUDENT BEHAVIOURS ASSOCIATED WITH
ORGANISING AND INTERPRETING INFORMATION

Behaviours	Student year group Year 7 (n = 10)	 Year 10 (n = 10)	 Year 12 (n = 10)
Number of students who recorded data	3	5	8
in tabular form	0/3[a]	1/5	6/8
with units	0/3	3/5	6/8
with column headings	0/3	0/5	5/8
Number of students who transformed data into a			
restructured table	0	0	2
graph	0	1	1
Number of students who made uncontrolled data interpretations	4	2	5

Note. [a] None of the three students who recorded data did so in a tabular form.

Only 16 of the 30 students recorded data; of these 16, seven recorded their data in ruled-up tables, nine included units, and five used column headings in their tables. Four students transformed their data into a form that would help them identify patterns in the data; two students collated their data into restructured tables, and two students constructed a graph to help determine the relationship between the independent and dependent variables.

All subjects made some attempt to interpret their experimental findings in terms of variables that influenced beam bending under load. Eleven students made uncontrolled data interpretations, that is, when comparing the bending observed in different trials these students failed to restrict such comparisons to trials that differed in terms of one variable. Only one subject was aware that a comparison of beams of different cross-sectional shape had to be performed using beams of the same cross-sectional area.

(4) Concluding

Once experimental work was completed students summarised their findings. Data regarding students' conclusions are presented in Table 4.

TABLE 4
STUDENT BEHAVIOURS ASSOCIATED WITH CONCLUDING

Behaviours	Student year group Year 7 (n = 10)	 Year 10 (n = 10)	 Year 12 (n = 10)
Mean number of valid factors identified [a]	1.1	1.8	2.5
Number of students who went beyond their data in drawing conclusions	5	5	1
Number who recognised methodological limitations of their investigation	0	2	5

Note.[a] These are the factors influencing beam bending that were identified and experimentally validated by the students.

Year 12 students, on average, identified and gathered experimental data to support 2.5 factors that influence the bending of beams under load. Year 10 students (1.8) and Year 7 students (1.1) were less successful in the identification and validation of factors influencing beam bending.

When prompted in the debriefing, all subjects attempted to apply their experimental findings to the problem of designing a bridge that would withstand heavy loads. Most subjects identified the need for thick beams and supporting columns placed close together. Half of the Year 7 and Year 10 students went beyond their data when recommending features for the design of the bridge whereas only one of the Year 12 students made this type of error.

In the debriefing, students were also asked how they would improve their approach to the investigation if given another opportunity to work on the problem. All students demonstrated little awareness of the methodological limitations of their investigations. Four subjects said they would take more care with measurements, one subject said he would do more written planning, another said she would test one variable at a time, and another said he would test more beams.

DISCUSSION

The subjects were confronted with a novel problem-solving task set in a real-world context. Expert problem solvers analyse problems and identify cues that activate relevant knowledge schemas to create a mental representation of the task that can facilitate the planning of appropriate solution processes (Chi et al., 1981). Several Year 7 students failed to represent the problem as a task requiring experimental testing of variables. Two Year 7 students performed no tests using the apparatus, only four made any measurements of bending, and only three students recorded any data. It seems that the Year 7 students lacked experience of systematic testing and measurement of experimental variables.

Previous studies of problem solving in science and social science indicate that extended periods of problem analysis and solution planning ultimately lead to efficient problem solutions (Larkin, 1979; Voss, Tyler & Yengo, 1983). The most notable feature of the students' work was their lack of problem analysis and planning before commencing on data collection procedures. Fifteen of the 30 students commenced work by identifying two or three potential independent variables and then almost immediately started manipulating the apparatus to test one of the variables they had identified. Very few students planned how they would apply or measure variables or record data before they commenced data collection procedures. There was no high level up-front metaplanning (Hayes-Roth & Hayes-Roth, 1979) of an overall approach to the problem. In fact most planning was low level, task specific planning in response to circumstances that arose during experimental work, typical of that revealed by previous research into adolescents' planning (Lawrence, Dodds & Volet, 1983). Many students demonstrated a lack of metacognitive control over processing (Schoenfeld, 1986). One Year 12 student performed the same repetitive measurement routine for 25 minutes without any overt monitoring or reflection on the usefulness of the process he was performing.

The students appeared to lack a well-developed schema for the structure of a controlled experiment. Only four students used the term hypothesis and no student used any of the terms variable, independent variable, dependent variable, control of variables, repeated trials or sample size while working on the problem. None of the students verbalised an intention to control variables. Miller and Driver (1987), and Rowell and Dawson (1989) would argue that reasoning skills such as control of variables are developed in particular contexts and are difficult to abstract and generalise to the level where they can be applied easily to novel tasks in unfamiliar domains. Many Year 12 students did however control variables at the level of being systematic in measurement procedures of which they would have had extensive experience.

The Year 12 students used effective measurement procedures taking care with zero values and parallax error. The high school students' relative success on the data collection phase of the investigation versus the planning and analysis phase is likely to be a reflection of the style of laboratory work to which students have been exposed. Analyses of the implemented curriculum in the USA (Tamir & Lunetta, 1981), Israel (Friedler & Tamir, 1984) and Australia (Tobin, 1986) indicate that most high school practical work involves recipe style exercises that are at the lowest level of openness to student planning (Tamir, 1989). Such exercises give students much practice in data collection procedures but no opportunity to practise problem analysis and planning.

The concluding phase of the investigation revealed two further limitations of the students' understanding of experimentation. First, half of the Year 7 and Year 10 students went beyond their data in drawing conclusions or applying their findings to the design of a bridge. Most of the Year 12 students were however more restrained in only drawing conclusions for which they had gathered supporting evidence. Second, even when prompted, very few students could identify limitations in their experimental procedures which suggests that they were unaware of the numerous interfering variables that influenced their experimental findings. It is likely that these students would place unwarranted confidence in their conclusions.

CONCLUSIONS

Results from this study indicate that students at all levels had poorly developed skills of problem analysis, planning and carrying out controlled experiments, basing conclusions only on obtained data, and recognising limitations in the methodology of their investigations.

Many of the Year 7 students failed to represent the task as one requiring experimental testing of variables, in fact most of these students did not make any measurements or record any data. Despite curriculum developments over the last twenty years there appears to be a continuing need to emphasise in the science curriculum of primary schools those activities where students are required to identify and manipulate variables, make measurements and record data.

The high school students showed gradual improvement in their abilities to successfully apply the process skills associated with measurement, data recording and some aspects of data interpretation. Their success on the problem-solving task was limited by ineffective problem analysis, planning, and control of variables.

If high school students are to develop a comprehensive repertoire of science investigation skills there is a need to modify the implemented curriculum to include more investigation style laboratory activities through which students can have the opportunity to practise the skills of problem analysis and planning controlled experiments. There is also a need to explicitly teach the conceptual knowledge regarding the structure of controlled experiments, particularly the concepts of hypothesis, independent, dependent and controlled variables.

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CHALLENGING PSEUDOSCIENTIFIC AND PARANORMAL BELIEFS HELD BY SOME PRE-SERVICE PRIMARY TEACHERS

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ABSTRACT

The widespread public acceptance of many paranormal and pseudoscientific claims should be of some concern to science educators who are striving to produce a scientifically literate community. There is ample evidence to show that students at all levels of our education system believe in aspects of pseudoscience based on claims and assumptions that are in conflict with accumulated scientific knowledge and a rigorous methodology. A survey was designed to assess primary and secondary science teacher-trainees' views. Afterwards 60 students were introduced to the notion of a 'fair test' and what constitutes 'evidence'. Demonstrations of psychic powers were provided and a video shown of professional water-diviners repeatedly failing to locate water under controlled conditions. A re-survey, 3 months later, indicated a rejection of many prior beliefs. However, almost half of the group retained their beliefs in miracles and E.S.P. whilst more than 40% retained their belief in visitors from outer space and that the solar system was created by a supernatural force.

INTRODUCTION

Many people within relatively "well-educated" Western communities, exhibit a readiness to believe almost any pseudoscientific claim that is made through the media. This problem appears to be compounded by the public's general acceptance as true almost any article that appears in print since few people can recognise what constitutes acceptable scientific evidence. As a result of this well-established theories which have greatly increased our understanding of evolution, planetary formation, plate tectonics and radiometric dating can be readily dismissed by uninformed individuals if such theories are used as counter-arguments against their belief in aspects of pseudoscience.

Children and adolescents represent groups which may be particularly vulnerable to media claims about alleged "mysteries" such as UFOs (Bainbridge, 1978), the creation of the World (Godfrey, 1983), the Bermuda Triangle (Kusche, 1975) and the presence of mysterious monsters (Guenette & Guenette, 1975: Snyder, 1977). Many other paranormal claims, although totally unsubstantiated, are equally likely to be believed by primary and secondary students. Such claims are those involving ESP (Marks and Kammann, 1980), metal-bending by psychic power (Gardner, 1981), astrology (Jerome, 1977), psychic archaeology (Jones, 1979) and water-divining, which is the main focus of this paper.

If we assume that it is primary and secondary students who are seeking clarification on pseudoscientific issues, then the responsibility for providing objective information might be said to rest with classroom teachers. They are the ones likely to be confronted with questions from curious students with an interest in widely publicised claims about paranormal phenomena or pseudoscientific activity for which there is no available evidence.

The investigation reported here initially considered the views on selected aspects of the para-normal, as held by primary and secondary teacher-trainees at a tertiary institution in Western Australia. These views, once identified, were compared with views held by tertiary students taking introductory science, sociology and psychology courses in two North American universities. The investigation aimed to provide experiences which might challenge the prevalent views held by teacher-trainees about the paranormal and, more specifically, water-divining.

THE INVESTIGATION

A questionnaire was designed to assess teacher-trainees' beliefs about several areas of pseudoscience and the paranormal. These included fortune-telling, contacting the dead, horoscopes, miracles, creation, UFOs, the Loch Ness Monster, ESP and water-divining. Water-divining was deliberately included since there are many individuals in Australia claiming to have the ability to detect underground water supplies using psychic powers. Some claimants readily acknowledge that they make a living out of their "abilities".

A video, which tested claims of water-divining ability, was shown to the teacher-trainees. It was hoped that this would challenge any prevailing beliefs they might have concerning the validity of water-divining as a skill or psychic gift.

SURVEY RESULTS FOR 1ST YEAR TEACHER-TRAINEES

Results for 1st year teacher trainees

A co-educational group (N=93) of 1st year students who had completed one semester of a 6-semester Diploma in Teaching (primary) programme was given the survey on pseudoscientific beliefs. Anonymity was guaranteed. The questions assessed their level of belief in the various phenomena. Responses "Definitely Yes" and "Yes" were combined on summation, as were responses "Definitely No" and "No". The overall results for this group are shown in Table 1.

TABLE 1
SURVEY RESULTS FOR 1ST YEAR TEACHER TRAINEES (PRIMARY) N=93.

		YES	UNSURE	NO
Q1	Fortune Telling	53%	27%	20%
Q2	Contact Dead	44%	18%	38%
Q3	Horoscopes	24%	13%	63%
Q4	Miracles	75%	19%	6%
Q5	Creation	49%	30%	21%
Q6	UFO's	54%	30%	16%
Q7	Loch Ness	31%	39%	30%
Q8	Water Divining	54%	32%	14%
Q9	ESP	69%	21%	10%

Results for 2nd year Students

A smaller co-educational group (N = 45) of 2nd year teacher trainees (primary) from the same institution was also given the survey. Results are shown in Table 2.

TABLE 2
SURVEY RESULTS FOR 2ND YEAR TEACHER TRAINEES (PRIMARY) N=45

		YES	UNSURE	NO
Q1	Fortune Telling	58%	18%	24%
Q2	Contact Dead	40%	22%	38%
Q3	Horoscopes	29%	7%	64%
Q4	Miracles	58%	33%	9%
Q5	Creation	47%	24%	29%
Q6	UFO's	67%	22%	11%
Q7	Loch Ness	29%	27%	44%
Q8	Water Divining	51%	33%	16%
Q9	ESP	71%	20%	9%

The response patterns are similar. Two notable differences emerge, however, with more 2nd year students expressing greater uncertainty about miracle-performers and the Loch Ness Monster. In terms of their belief in water-divining, a majority of both groups accepted the claims that some people possessed a special ability, enabling them to find underground water.

Survey results for teacher-trainees (secondary) having some science background.
Primary teacher-trainees have generally been exposed to little formal science education beyond year 10 at the secondary school level. Consequently, this lack of background might result in paranormal beliefs being more prevalent amongst these groups. Secondary teacher-trainees, possessing a more solid background in the physical and/or biological sciences, might tend to be more skeptical when considering pseudoscientific claims since they may be more likely to recognise and better assess available evidence for such claims. A co-educational group (N = 33) of secondary teacher-trainees was selected from the same tertiary institution in Western Australia. It was established that 18 of these students held science degrees and were completing a one year Diploma in Teaching programme. The remaining 15 non-graduate students had completed 2 years of formal science courses as part of their 3 - year science-major programme for secondary teacher-trainees. The two groups have not been distinguished in terms of questionnaire responses. The results from this survey are shown in Table 3.

When results were compared with those previously obtained from the 138 primary teacher trainees, it was noted that the tendency for secondary teacher trainees to believe in the pseudoscientific claims was generally lower. More than 50% of the science teacher-trainees rejected the notion of creation, although it still remains of some concern to find that over half of the students, from each of the three groups, were not willing to reject beliefs in fortune telling, communicating with the dead, miracles, UFOs, the Loch Ness Monster, water-divining and ESP, ie. all of the pseudoscientific beliefs itemised in the survey with the exceptions of horoscopes and (in the case of science students) creation.

TABLE 3
SURVEY RESULTS FOR SCIENCE TEACHER TRAINEES
(SECONDARY) N=33

		YES	UNSURE	NO
Q1	Fortune Telling	52%	18%	30%
Q2	Contact Dead	24%	31%	45%
Q3	Horoscopes	21%	9%	70%
Q4	Miracles	49%	18%	33%
Q5	Creation	33%	9%	58%
Q6	UFO's	46%	27%	27%
Q7	Loch Ness	27%	27%	46%
Q8	Water Divining	43%	27%	30%
Q9	ESP	61%	21%	18%

Comparison of these data with some North American findings

A comprehensive survey of tertiary students' pseudoscientific beliefs was conducted at the Central Connecticut State University (Feder, 1986). The students (N=186) were a representative sample of those attending introductory courses in archaeology, anthropology, biology and sociology.

Fifty items appeared on Feder's questionnaire, although for the purpose of comparison, only those items which considered the domains, in the present survey, will be listed here (Table 4).

TABLE 4
SELECTED DATA FROM FEDER (1986, pp. 182-183) N = 186

		PERCENTAGE		
		BELIEVE	UNSURE	DISBELIEVE
1	Some people have the ability to predict future events by psychic power	56.9	15.1	28.0
2	Some people can read other people's thoughts by psychic power	53.2	16.7	30.1
4	The Loch Ness Monster really exists	28.5	42.5	29.0
6	UFOs are actual spacecraft from other planets	37.6	38.2	24.2
7	There is a God	76.4	14.5	9.1
12	Astrology is an accurate prediction of people's personalities	24.2	22.0	53.8
15	It is possible to communicate with the dead	17.8	33.3	49.0
28	God created the universe	62.3	21.0	16.7

The Western Australian data parallel Feder's data in that the majority of both tertiary groups expressed a belief or some uncertainty about fortune-telling, communicating with the dead, miracles, creation by supernatural forces, UFO's the Loch Ness Monster and E.S.P.

Another North American survey was initiated by Gray (1984) at Concordia University, Montreal. Students attending introductory psychology courses (N = 125) were assessed on their beliefs concerning ten paranormal phenomena: ESP (including telepathy, clairvoyance and psychokinesis), UFOs (as extraterrestrial spacecraft), astrology, ghosts, Bermuda Triangle, Von Daniken's claims, psychic healing, miracles, biorhythms and reincarnation. The percentage of students saying "yes", i.e. they believed in such pseudoscientific claims, ranged from 43% (ghosts, miracles) to 85% (ESP).

Twelve months after the survey of 45 primary teacher-trainees a similar group (N = 60) of 2nd year students was given the same questionnaire on pseudoscientific and paranormal claims. This second group was undertaking the same Diploma course as the first group. The results from this (pre-test) questionnaire are shown in Table 5.

TABLE 5
SURVEY RESULTS FOR 2ND YEAR TEACHER TRAINEES (PRIMARY)

		PRE-TEST (N=60)			POST-TEST (N=63)		
		YES	UNSURE	NO	YES	UNSURE	NO
Q1	Fortune Telling	60%	12%	28%	35%	11%	54%
Q2	Contact Dead	28%	32%	40%	13%	20%	67%
Q3	Horoscopes	28%	12%	60%	13%	14%	73%
Q4	Miracles	49%	18%	33%	46%	24%	30%
Q5	Creation	75%	12%	13%	43%	17%	40%
Q6	UFO's	52%	28%	20%	40%	33%	27%
Q7	Loch Ness	58%	24%	18%	16%	22%	62%
Q8	Water Divining	67%	16%	17%	22%	19%	59%
Q9	ESP	72%	16%	12%	46%	13%	41%

Some clear similarities are evident between both 2nd year groups, (Tables 2 and 5) in their responses to questions dealing with fortune-telling, horoscopes, creation, UFOs, ESP and water divining.

The later group was to be exposed to a planned teaching strategy, designed to challenge any general views about pseudoscientific claims and, more specifically, these views concerning water-divining. This "treatment" group tended to be more unsure about claims concerning "communication with the dead" and "The Loch Ness Monster", although the group appeared to be more convinced that miracles had been, or could be performed by some individuals.

Across both groups of 2nd year teacher-trainees (N = 105) approximately 61% believed in claims of water-divining ability. Individual interviews with randomly selected "believers" produced anecdotes about relatives and/or friends who had "successfully" directed farmers to locations where they should drill for water. Hearsay "evidence" was also offered as proof of some people having water-divining powers. Only 16% of students, from both 2nd year groups, rejected claims of water-divining powers.

Following the survey of the 60 2nd year teacher-trainees, this group participated in a two hour lecture/discussion which dealt with the notion of "evidence" and what sets real evidence apart from hearsay and so-called anecdotal "evidence". Examples of erroneous and misleading newspaper articles were provided for discussion, eg. The Perth Sunday Times article on the Mysterious Face on Mars (August 17th, 1986, pp59-60). Additionally, discussion was initiated over fabricated accounts of pseudoscientific claims e.g. Chariots of the Gods (Story, 1976) and the Bermuda Triangle (Kusche, 1975). The main thrust of this teaching session was to demonstrate the inability of professional water-diviners to locate underground water during a controlled experiment which the "diviners" themselves helped to design and run.

A video was shown to the group of teacher-trainees with the theme being that of testing water-diviners under the scrutiny of professional magician James Randi. (The assistance of the Dick Smith Organization in providing this video is gratefully acknowledged). Strategically inserted in the film were demonstrations by Randi which showed the kinds of trickery employed by "psychics" such as Uri Geller and psychic "surgeons" similar to those currently practising in the Philippines. The "cream" of Australia's water-diviners were assembled and given a unique opportunity to demonstrate their abilities and a $40,000 prize was available to any one of them who might be successful. The "diviners" assisted with every stage of the experimental design and were present for the laying down, covering and test-running of the ten large plastic irrigation pipes which they later had to identify as carrying water or otherwise. The irrigation pipes were laid parallel, and when covered with soil, were then selected at random by independent judges so that water could be passed through them. Each "diviner" (out of sight of their colleagues) selected the pipe through which they believed they could detect the flow of water. Interestingly all "diviners" were able to "select" the correct pipe by use of divining rods when they were shown which pipe the water was running through. The opportunity to "tune-in" their rods was provided before the randomised testing commenced. This video unequivocally demonstrated how professional water-diviners failed to prove their powers. None was successful in detecting water at better than 10% accuracy which was the level that any person might have attained by chance alone. As predicted by James Randi, the "diviners", having been provided with the test results, proceeded to rationalise their failures with reference to the impact of factors such as sunspot activity, and residual moisture in the pipes.

Post-Video Discussion and Re-Survey

Discussion with the 2nd year teacher-trainees followed the video on water-divining and many from the group clearly indicated their surprise at the diviners' inability to detect underground water under test conditions. One spin-off from this video was the obvious impact made by James Randi's demonstration of spoon-bending and psychic surgery. The students' initial perceptions of such pseudoscientific claims were clearly challenged and beliefs changed in many cases. It was likely that, for some of the students, any changes in their belief about the paranormal might be of a short-term nature only and therefore it was suspected that some regression might occur over longer periods of time. Consequently, the questionnaire was administered three months later in order to probe longer term retention of belief systems about paranormal and pseudoscientific claims. Results from this post-video survey are shown at the right of Table 5.

SUMMARY

The majority of 2nd year teacher-trainees, monitored over a three month period, clearly demonstrated a rejection of beliefs in water-divining. A further outcome was a general decline in their acceptance of all pseudoscientific claims itemised in the survey although there was little change in beliefs in miracles. Comments from several students, interviewed after the three month survey, indicated that the video and discussion had a very real impact on their prior beliefs.

Such promising results, which may have experienced some reversal over more extended periods of time (Gray 1984; Happs, 1985) should still be viewed in light of the fact that almost half of the teacher-trainees involved in this investigation retained their beliefs in miracles and ESP. Additionally, more than 40% of the group retained their belief that UFOs represent visitors from outer space and that the Earth and solar system were created by a supernatural force.

If the beliefs identified in this investigation are representative of those held by teacher-trainees throughout Australia, then a situation exists whereby many of our future teachers, when asked for their professional opinions on paranormal or pseudoscientific matters, are likely to promote misconceptions in these areas. The spread of such beliefs in this way may prove difficult to resist.

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INTEGRATING QUALITATIVE AND QUANTITATIVE METHODS TO MONITOR AN INTERVENTION PROGRAM

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ABSTRACT

Teachers in one-teacher schools have often experienced problems when implementing enquiry-based science programs. An innovation was developed to address these problems in isolated one-teacher schools in the far-west of NSW. It consisted of 18 science kits and an associated teaching sequence. Each kit contained 15 student activity sheets, equipment and supplementary resources. An intervention program was designed to support the implementation of the innovation. The purpose of this study was to monitor the teacher's process of change and to ascertain the outcomes of the intervention program in one of the schools. Data were collected using diagnostic dimensions from the Concerns-Based Adoption Model Project as well as qualitative methods. The results indicated that the teacher's concerns about the innovation focused on how it affected the students. The teacher used the innovation to support her student-centred teaching methods and the students had positive perceptions about learning science.

INTRODUCTION

The Department of Employment, Education and Training (1989) in its Discipline Review of Teacher Education in Mathematics and Science stated, "Science in Australian primary schooling is thus in a state of crisis, and the panel does not believe that this situation is recent" (Vol. 1, p. 81). Several authors (Education Department of South Australia, 1982 ; Gibbs, 1988) supported this view and commented that many primary teachers have experienced difficulties when implementing science programs. These studies revealed that most primary classes spend no more than 45 minutes (4.5% of teaching time) on science each week, and that many teachers lack confidence to implement the subject.

Harlen and Osborne (1985) stated that this situation was apparent in other countries. They contended that the reasons for these difficulties were the teachers' lack of background knowledge as well as insufficient resources and understanding of enquiry-based science teaching. A number of curriculum innovations have been designed to assist primary teachers implement science, but many of these have not been successful. James and Hord (1988) reported that many elementary science curriculum innovations introduced in the USA failed because they were not effectively implemented. In Australia, Malcolm (1984) also referred to the problems created by inadequate implementation procedures:

> Thus, at both primary and secondary levels, part of the failure of the curriculum packages was failure in implementation due to inadequate attention to re-educating and supporting teachers to make good use of

> the materials. Teachers like the rest of us, have attitudes and habits that are not easily shifted. (Malcolm, 1984, p. 9)

BACKGROUND OF THIS STUDY

Teaching in a one-teacher school is a demanding position due to the geographic isolation of the school and the responsibility of teaching the K-6 students together in one room. In 1988, a number of teachers in these schools in the far-west of NSW reported to their local educational supervisor that they did not have the time or resources to implement science effectively. In response to these requests, this writer coordinated a project to develop and implement an innovation to address their needs.

Over a period of two years, an innovation was developed collaboratively with the teachers which consisted of two parts: (1) Eighteen kits to satisfy the requirements of the K-6 science syllabus in NSW. Each kit had 15 student activity sheets and necessary equipment packed in a large plastic tub. The kits were designed for the students to use so that the teacher could assume the role of a facilitator in her classroom and help individual groups. (2) A teaching sequence designed to encourage the students to be independent learners when conducting problem-solving activities in the classroom (Hoban, 1991).

An intervention program was planned to support the implementation of the innovation. This commenced with a two-day inservice course in July, 1990 and continued for six months with follow-up visits by this writer who was a K-12 Science Consultant for the Department of School Education. Data were collected before, during and after the intervention program.

The purpose of this study was to monitor a teacher's process of change over 12 months and to ascertain the outcomes of the intervention program in her school. There were two central research questions: What were the prime concerns of the teacher toward the innovation? How did the teacher change with her use of the innovation?

PROCEDURE

This study attempted to gain an understanding of the process of change as experienced by the teacher. A number of authors (Goetz & LeCompte, 1984; Patton, 1987) recommended that a case study methodology was appropriate to explore a situation in which an intervention is introduced to individuals:

> Case studies are particularly valuable when the evaluation aims to capture individual differences or unique variations from one program setting to another, or from one program experience to another...the more a program aims at individualising outcomes, the greater the appropriateness of qualitative case methods. (Quinn Patton, 1987, p19)

This study incorporated a case study design using a combination of quantitative and qualitative data gathering methods. Yin (1985) defined a case study as: an empirical inquiry that

- investigates a contemporary phenomenon within its real-life context; when
- the boundaries between phenomenon and context are not clearly evident; and in which
- multiple sources of evidence are used. (p.23)

A number of authors (Goldstein & Rutherford, Note 1; Patton, 1987; Lawrenz & McCreath, 1988) recommended using complementary data gathering methods to monitor intervention programs. Lawrenz and McCreath (1988) stated, "the qualitative components provide richness to the data and are a valuable source for identifying potentially relevant variables. The quantitative components provide the "hard" data necessary to document the degree of the effects" (p. 406).

In this study, diagnostic dimensions developed for the Concerns-Based Adoption Model (CBAM) Project (Hall, Wallace & Dossett, 1973) were used to provide numerical data. Qualitative methods were used to crosscheck the data from the CBAM instruments. This method was tried out and recommended by Goldstein and Rutherford (Note 1) for the purpose of monitoring intervention programs. The data gathering methods are explained below:

1. The Stages of Concern questionnaire (SoC) as described by Hall, George & Rutherford (1979) is a 35 item questionnaire to identify the concerns of the teacher toward the innovation.
2. The Levels of Use interview (LoU) as described by Loucks, Newlove and Hall (1975) is a semi-structured interview to diagnose the degree of use of the innovation.
3. The Innovation Configuration (IC) as described by Heck, Stiegelbauer, Hall and Loucks (1981) is a checklist to diagnose which parts of an innovation are being used.
4. Semi-structured interviews (IT) with teachers which were taped, transcribed, coded and analysed.
5. Semi-structured interviews (IS) with students were conducted at the end of this study to ascertain their perceptions about learning science. These were conducted by another researcher to avoid bias. A tape recorder was used and then the data transcribed.
6. Participant observations, which took the form of lesson observations, were coded and analysed (LO).
7. Document observation of the science workbooks of the students (Doc). These were monitored to provide continuous data.
8. Log sheet to be filled out by teachers(Log).

The frequency of use of the different data gathering methods is represented in Table 1 by an X.

RESULTS

The Teacher's Concerns about the Innovation

The concerns of the teacher toward the innovation were monitored using the Stages of Concern questionnaire and interview data collected regularly throughout this study. The questionnaire was administered three times (22-8-90, 12-11-90, 24-7-91). Procedures followed were in accordance with those recommended in the manual by Hall, George and Rutherford (1979) who suggested that the instrument could be used with groups or individuals. They recommended that all interpretations should be treated as hypotheses, as the validity of the data is determined by the genuineness of the responses and skill of the interpreter. Interpretations were crosschecked using data collected from teacher interviews.

TABLE 1
FREQUENCY OF USE OF DATA GATHERING METHODS

	Pre Intervention			|← During Intervention →|						Post Intervention	
	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Apr.	July
	1990									1991	
SoC					X			X			X
IC			X		X	X	X	X	X	X	X
LoU								X			X
IT			X		X	X		X		X	X
IS									X		X
LO			X		X	X	X	X	X	X	X
Doc	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Log.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										

Hall, George and Rutherford (1979) maintained that the concerns of a teacher about an innovation could be represented by collecting data to represent a profile of concerns at seven stages: awareness, informational, personal, management, consequence, collaboration and refocusing. A profile which represented a high intensity on the first three stages, awareness, informational and personal would generally indicate non-use of the innovation. A profile which represented a high intensity at the management stage would generally indicate a beginning user, with concerns about the task of organising the innovation. A profile which represented a high intensity on the last three stages, consequence, collaboration and refocusing would generally indicate concerns focused on the students, and a more experienced user of the innovation. The results of the questionnaires for the teacher monitored in this study are represented in Fig. 1.

The profiles in Fig. 1 indicate that the teacher was a user of the innovation throughout the intervention program. The first profile (22-8-90) indicated that the teacher was mainly concerned about the impact of the innovation upon her students (consequences) and how the innovation would be shared with the teachers at the other schools (collaboration). The second profile (12-11-90) indicated that the teacher was less concerned about the impact of the innovation on the students and more concerned about adding her own ideas to the innovation (refocusing). The third profile (24-7-91) indicated that the teacher's concerns were concentrated on refocusing which indicated that the teacher was concerned about modifying the innovation.

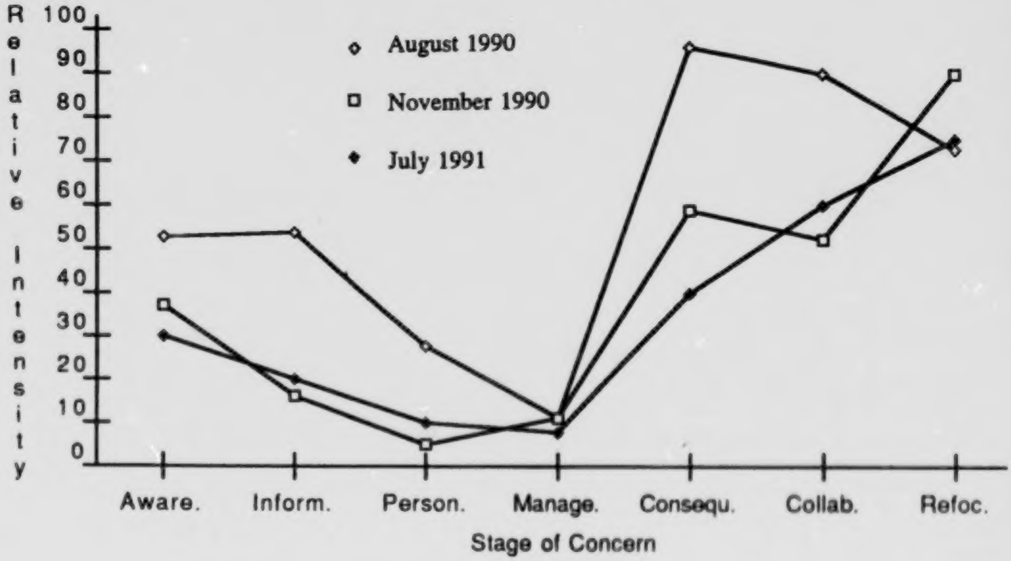

Fig. 1 SoC Profiles of Teacher

These inferences were confirmed in the interviews with the teacher during and after the intervention program. Statements by the teacher regarding concerns about the innovation are shown in Table 2. The statements show that the teacher believed that the kits addressed the problems of lack of preparation time and resources and that the students found them easy to use. The manual (Hall, George & Rutherford, 1977) suggested that it was unusual for beginning users to have such low concerns at the personal and management stages. This was an indication that the teacher and students found the innovation user-friendly which is supported by her statements in Table 2. Her main concern was not about the effects of the innovation on herself or the task of organising the kits, but rather about the effects of the innovation on the students. During the interviews, this writer supported the teacher's use of the innovation and encouraged her to find other extension activities for the students. At the beginning of 1991, her cluster group formulated a maintenance policy which was reflected in the lowering of her concerns about collaboration. Her statements about seeking extension activities confirmed the third SoC profile which indicated a high concern for refocusing.

Use of the Innovation by the Teacher

The second research question referred to how the teacher changed with her use of the innovation. This was addressed by using the Innovation Configuration (IC) checklist, which identified the parts of the innovation being used as well as qualitative methods. The IC was devised in accordance with procedures recommended by Heck, Stiegelbauer, Hall and Loucks (1981). Information collected using the IC checklist was cross-checked with data from the Levels of Use (LoU) interview, lesson observations, log sheet, interviews and documents (reports written by the primary students).

TABLE 2
INTERVIEW STATEMENTS BY THE TEACHER REGARDING CONCERNS ABOUT THE INNOVATION

Stage of Concern	Before the intervention 11-6-90	During the intervention 24-8-90	After the intervention 26-7-91
Personal	The kits will assist my planning and they will help to solve my problems of time and resources.	I call them user friendly because the kids can use them and I can supplement them.	They make science easier to teach because the kids can use them themselves and I can help individuals.
Management	The biggest problems are time and materials. In a small school your science lessons are restricted by the time and limited resources that you have.	I think the kits are great because all of the materials are in the kits and I'm not running around .... trying to get all of the materials.	Most of the materials are in them and the activity sheets are easy to read.
Consequence	It is very difficult to help individuals in a hands-on activity when you have such a wide variety of ages and abilities.	The sheets are easy for the kids to use so I've got time to help the younger ones.	The children understand the sheets and the language in them is at their level.
Collaboration	I hope that the cluster can share ideas through the kits.	I've run a science fair with two other schools. We just gave a kit to each of the parents and the students went from group to group.	We have a maintenance plan and we all voted to put in money to replace what we use in the kits.
Refocusing	I hope I can add my own ideas.	I am looking for additional ideas and information from people and books. There needs to be a step where the skills are named. You should be able to name the skills before the activity. I incorporate this into the gather stage.	They give you an introduction and are easy to supplement. I would put in more extension activities.

The IC was trialled in a pilot study and revised to be made up of five components: lesson content, activity sheets, equipment, instructional strategy and reports. It had five variations for each component except for lesson content, which had four variations. Use of the innovation components (activity sheets, equipment, instructional strategy and reporting) were rated in this way: a variation of one to two was unacceptable, a variation of three to four was acceptable and a variation of five was ideal. For lesson content, a variation of four was rated as ideal. Data were collected for each of the components before the intervention, during the intervention and after the intervention and are displayed in Table 3.

TABLE 3
INNOVATION CONFIGURATION CHECKLIST RESULTS FOR THE TEACHER

Innovation Component	12-6-90 Pre-Interv.	24-8-90	12-9-90 During	12-10-90 Intervention	12-11-90	16-4-91 Post	26-6-91 Intervention
1. Lesson content	1	4	4	4	4	4	4
2. Activity Sheets	1	5	4	5	5	5	5
3. Equipment	3	5	5	5	5	5	5
4. Instruct. Strategy	3	5	5	5	5	5	5
5. Reports	3	5	5	5	5	5	5

It should be noted that data collected before the intervention was only used as a guide to ascertain how the teacher taught science because she did not have access to the innovation at this stage. Data in Table 3 indicate that after the initial inservice in July, the teacher used each of the five components of the innovation at an ideal level. This means that the teacher was using the innovation in the way which it was intended to be used by the designer:
* the teacher was using the innovation for the whole of her science lesson;
* the teacher was allowing the students to use the activity sheets;
* there was enough equipment for all of the students to use themselves.
* she was teaching science using an instructional strategy which was student-centred;
* the students were recording their investigation informally using their own words.
These findings were confirmed by data collected from other methods (Levels of Use Interview, lesson observations, log sheet, interviews and science books of the primary students) as displayed in Table 4 .

Although the focus of this study was on the teacher to monitor her process of change, students were selected at random and interviewed to ascertain their perceptions about learning science. This data information would help to ascertain the outcomes of the intervention program. The following interview with two year 4 children was conducted at the end of the intervention program by another researcher (L. A.). The interviewer had constructed a model of a windmill which was similar to the activities in the innovation. The windmill had some deliberate faults. A transcript of the interview:

L. A. : Here is the pin wheel that I made quickly with materials that I found at home. Do you have anything like this at home?
Tony: A windmill.
L. A. : If this was one of your windmills would it work very well?
Belinda: No.
L. A. : How could you make this windmill better?
Tony: You could put the hole in the centre and it would work better.
L. A. : What else?
Belinda: Take away the rough stick and put a smooth one in.
Tony: You could put some more blades in.
L. A. : So if you were with Mrs....., what sorts of things would you say?
Tony: Put more blades in, put a smoother stick in and put it in the middle then you would test it to see if it works better.
L. A. : How often would you do things like this?

TABLE 4

QUALITATIVE DATA RELATED TO INNOVATION COMPONENTS

Innovation Component	Before the Intervention Feb.1990-June 1990	During the Intervention July 1990-Dec. 1990	After the Intervention Feb.1991-July 1991
Lesson Content	• Teacher selected a topic for each term. There was no program for the year. • Student books revealed that the topics of magnets and birds were covered so far this year with 13 lessons recorded.	• Teacher commenced innovation topic "Skeletons and Bones" immediately after initial inservice. • Student books revealed that all 20 lessons recorded were from innovation. • Log sheet confirmed that all lessons were from the innovation.	• Student books revealed that all lessons were from innovation. • Log sheet confirmed that all 18 lessons were from the innovation. • " the kits have become my program." (16-4-91)
Activity Sheets	• Student books revealed that worksheets were used in one of the 12 lessons during this time. These were only used to record results. • Log sheet confirmed this. • " We occasionally use worksheets for recording. " (12-6-91)	• Student books revealed that activity sheets were used in each of the 20 lessons. • Log sheet confirmed this. • " the activity sheets are easy to read, the children understand them and the language is at their level... They are given the sheets and as you pointed out in the inservice, you let them do as much as possible without my interference." (24-8-91)	• Student books reveal that activity sheets were used in each of the 12 lessons. • Log sheet confirmed this. • " the sheets make them independent. I can mix up the kindies with the primary kids because the older kids can use the sheets." (16-4-91)
Equipment	• Log sheets indicated that equipment was used in most lessons. • " the biggest problems are time and equipment." (11-6-90)	• Log sheet indicated that equipment was used in all lessons. " the main strengths of the kits are that they have the materials in them and the sheets are easy to read." (24-8-90)	• Log sheet indicated that equipment was used in all lessons. • " The kits are user friendly and come with all of the materials. They can also be used in supplementary activities." (16-4-91)
Instructional Strategy	• "What we do is have a discussion the day before just as they are about to go home about the lesson they are going to have the next day so the children are focusing on the skills we are going to practise." (12-6-90)	•" I like it because it makes the children think more and so they can get more out of the activities. It makes the children look at the variables. The younger ones are able to learn from the older ones. It gives the students steps for thinking about the activity and ideas to design and trial. " (12-9-90)	• " the best part is that the kids are used to it so they are aware of how they are going to investigate an activity. We sometimes have variables competition to see who can think of the most. They are getting better at improving activities because they are thinking more." (16-4-91)
Reports	• " The students each have a science book. They record in a number of ways, they may use a worksheet , copy from the board, sketch a diagram or often make up their own recordings." (21-6-90)	• Reports are written in a personal tone and describe what happened and why in the children's own words. Variables are listed .	• Reports written in a personal tone. They describe what happened in the activity as well as listing variables and explanations.

Belinda: Every Wednesday we do science except when we have got something special like the Eisteddfod.
L. A. : Do you like doing science?
Tony: I love it.
Belinda: I like it too because it is fun to do and if you don't always get things right you keep on trying until you get it.
L. A. : How do you do science?
Tony: Mrs... give you a piece of paper and you read it.
L. A. : What do you mean?
Tony: She gives you the science paper.
L. A. : What do you do with it?
Tony: You have to get all the things it says and then you go outside or stay inside and just do it.
L. A. : Where do you get the things from?
Tony: We get the things from the box.
L. A. : So, after you do the activity, what happens?
Tony: You write a report and go over the variables and you have to think about them.
Belinda: We usually go on the floor and have a talk about what variables there were and then put them up on the board.
L. A. : What happens then?
Tony: We go back to our desk and do our report.
L. A. : What do you write?
Belinda You have a look at the sheet and you go over what what you did and how you did it, what went quickest or what worked best.
L. A. : Do you copy this from the board?
Tony: No, we write it like a story.
Belinda: Mrs... puts the variables up on the board and we use them. You don't have to use all of them but you can use some of them.
L. A. : So if I was doing a report on this what would you say?
Tony: Today in science we tried to make a windmill. At first it did not work but we added more blades and a smoother stick.
Belinda: Yeah and tightness, it has to be loose to spin but not not too loose and you need wind.

DISCUSSION

The results indicated that the teacher changed the way she taught science as a consequence of the intervention program. At the beginning of the program, she had high concerns about the effects of the innovation on the students but this reduced over the twelve months. During the study, she was concerned about finding extension activities for the innovation. The teacher used the innovation as intended by the developer which was reflected by her student-centred instruction. The students interviewed had positive perceptions about learning science which was enquiry-based.

CONCLUSION

The teacher had identified that her main problems which hindered her teaching of science were a lack of resources and preparation time. The innovation addressed these problems by providing kits for the students to use and a teaching sequence. The primary children were able to use the activity sheets and equipment themselves and so they became independent learners. This enabled the teacher to assume the role of a facilitator in her own classroom so that she could help individual groups. The main outcomes of the intervention program were that the teacher was able to use the innovation to support her student-centred methods of teaching science and it became the basis of her science program.

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CHANGING PRIMARY TEACHER TRAINEES' ATTITUDES TO SCIENCE.

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ABSTRACT

A study of primary teacher trainees' perceptions and attitudes to science in 1990, has been useful in designing a semester unit aimed at increasing the confidence and interest of first year students at Victoria College. This paper outlines the background survey and discusses some of the results and how they were used to develop the Professional Readiness Study - Understanding Science. This unit attempts to change attitudes by focussing on metacognition and encourages students to understand and control their own learning. Discussion involves teaching and learning strategies and alternative assessment approaches including the student's journal - the Personal Record.

INTRODUCTION

Teachers are expected to take more responsibility for their own professional development. Two projects involving Baird - The PEEL project (Baird & Mitchell 1986) and TLSS (Teaching and Learning Science in Schools) (Ross et al., 1988) - highlight the importance of teacher initiated change. A project to develop self-help materials for small groups of teachers (Teaching technology in science, Note 1) has as its starting point teachers' needs and where they are in the life of the school. Innovative teaching is usually generated by highly motivated and interested teachers who are willing to modify traditional teaching approaches and to change their view of good teaching. Many teachers feel that they lack confidence and expertise in the science and technology areas. Yates and Goodrum (1990) in a study of Perth primary school teachers' attitudes to science, identified the statistic of most concern as being: "28% of teachers lacked the motivation to teach science." They concluded:

> It is important for strategies to be found to tackle the problems associated with teachers' lack of interest and confidence in teaching science (especially physical science) in the primary school.

This paper focusses on teacher training in order to develop teachers who have both the interest and confidence to teach science to young children. We believe the place to start to rectify the problems is with trainee teachers and their courses. Preservice primary school teachers also lack confidence in teaching science as outlined in the national Discipline Review of Teacher Education in Mathematics and Science (1989). The review recommends an increase in the amount of science taken by primary teacher trainees, particularly in the area of background science knowledge and in identification of "gaps that can be remedied by suitable bridging studies." This recommendation has been implemented at Victoria College by introducing into the Bachelor of Teaching course a unit called Professional Readiness Study - Understanding Science.

First year students who do not choose science as a general study and who have a poorbackground in science are required to complete this unit which involves three contact hours per week for one semester. The unit is designed to promote more positive attitudes towards science and to increase student confidence and interest in science.

CONTEXT AND AIMS OF THE RESEARCH

A study of trainee primary teachers was carried out by Martin et al. (Note 2) and the results used in planning the Professional Readiness Study - Understanding Science (PRS) unit which addresses the problems highlighted by the research. The aim of the research was to establish primary teacher trainees' knowledge, perceptions and attitudes toward science on entry to Victoria College and at the beginning of courses in science, and to monitor the effectiveness of strategies employed in these courses in terms of the impact on these. The mixing of students with and without science backgrounds provided an ideal opportunity to compare their perceptions of and attitudes to science and science teaching. The PRS unit development incorporated ideas from the research findings and it also took into account the view of Edwards (1990) who argues that

> Greater emphasis on ignorance would result in students being aware of their own understandings and able to ask when they do not know. It could readmit joy, paradox and mystery into science education. Such a change in emphasis would need to permeate science teaching in all levels from primary to tertiary and would need to impact science teacher education programs and state science syllabi.

Research questions identified in the study of trainee primary teachers.

- How do incoming teacher trainees perceive science in relation to their own learning, and its relevance to teaching in Primary schools?
- What perceptions and attitudes toward science do third year students, who have had no formal tertiary contact with science, have in relation to their own personal growth and to their teaching?
- What are the determinants of these perceptions and attitudes?
- How do perceptions and attitudes of science students alter as they progress during the course?
- To what extent can features of a science curriculum unit effect an improvement in attitudes to the teaching of science?
- Which factors within the science unit, and the course in general, affect students' perceptions of and attitudes to science?
- To what extent is confidence in science knowledge a determinant of student teacher willingness to teach science?

RESEARCH DESIGN

Teacher trainees' background in science and their attitudes to science and science issues were explored by means of structured and open-ended questions in a questionnaire.

The survey of 121 first year students who chose Science 100 as one of their two general studies units and 346 third year students who were required to study Competence and Methodology in Science was completed in semester one and two, 1990. The sample included a control group of first year students not studying science. Interviews with 15 randomly selected students occurred throughout the year.

RESEARCH FINDINGS

Most students entering the course are female and few have studied any physical science in Years 11 and 12 (Table 1).

TABLE 1
FIRST YEAR STUDENTS' YEAR 12 SCIENCE EXPERIENCES

	CONTROL		SCIENCE 100	
Year 12 Science subjects taken	Males (N=13) %	Females (N=53) %	Males (N=17) %	Females (N=104) %
NO SCIENCE	69	58	29	28
BIOLOGY	23	36	65	70
PHYSICS&/OR CHEMISTRY	8	6	24	9

Given the under-representation of girls in science beyond the compulsory level reported in a number of sources [for example The National Policy for the Education of Girls in Australian Schools, (Dawkins, 1987)] these data are not unexpected.

Table 1 shows that the science studied in year 12 is usually Biology and that students without science tend not to choose Science 100. Of those who do, the males have had more physical science experiences than the females. These data support an earlier report (Owen et al. 1985) in which Victorian science lecturers in preservice primary teacher education, identified that most students, mainly female, had poor academic backgrounds in science, especially in the physical sciences, and had negative attitudes to science. A later study showed that on completing the course the students' attitudes to science were more positive with a greater improvement evident in those students who had had few science experiences at secondary school.

The study of Competence and Methodology (C&M) in Science exit students at Victoria College supports Owen's findings as 75% of students indicated that their attitudes towards teaching science had changed during the final year. Reasons given included:

- more positive and confident about teaching science
- personal interest in science has increased
- appreciate the value of integrating science with other subjects
- increased awareness of science content, references and strategies
- 'hands-on' component is fun and a good learning experience.

Students were asked to list the three aspects of the C&M course which they felt effectively prepared them to teach primary science (Table 2).

TABLE 2
EFFECTIVE ASPECTS OF THE CURRICULUM AND METHODOLOGY IN SCIENCE COURSE

ASPECT RELATING TO SCIENCE	(N=385) %
'Hands-on' activities in class	34
Working with small groups of children	13
Resources information	12
Children's ideas about science	9
Integrated curriculum	10
Links between science and technology	8
Student's own attitudes to science	7
Current developments in primary science in Victoria	4
Personal development in science	2
Gender equity in science	1

Clearly, the students believe that the "'hands-on' activities in class" form the most important aspect of the course. The statistics show that most students perceive the aspect "student's own attitudes to science" as having little effect in preparing them for teaching science. This may be interpreted as the C&M course itself placing little emphasis on this aspect or it may have had a minimal effect on changing the students' attitudes. Either way the data highlight the need for the course to address this aspect. Students who chose the aspect "students' own attitudes to science" indicated that the course provided increased understanding and awareness of science content which increased confidence to teach science, made attitude toward science more positive, and related science knowledge to present world affairs.

The degree to which the amount of background knowledge of science was useful to the C&M student was also explored.

- 72% of Science Majors (students who chose Science as an elective) - felt that their major studies in science had helped them to better understand the topics presented in C&M.

- 46% of Non Science Majors (students who did not chose Science as an elective) felt that a more extensive background of science studies would have given them a better understanding of the topics presented in C&M.

The students thought it would help them to understand the concepts/content and that they would be more prepared and positive. Some thought that they had a poor background in science and that the science majors had an advantage.

PROFESSIONAL READINESS STUDY - UNDERSTANDING SCIENCE

This unit has been incorporated into the first year of the Bachelor of Teaching course to give students with limited background, experiences in the physical sciences which should help generate increased confidence and interest, thus better preparing them for the C&M course.

Rationale.

The College believes that all students should have an adequate background in all subjects and has structured the first year course to include compulsory Professional Readiness Studies, to introduce students to areas with which they are unfamiliar. Students select two out of the four PRS studies offered: The Arts, Science, Personal Development and Social Education. If students choose Science as a general study they cannot enrol for science as a PRS. The PRS Understanding Science unit is intended to address the issue of background and confidence in science in incoming students. It is designed particularly for those students who have not undertaken significant studies in physical science units at VCE level, or for students who have, but feel that additional studies in science would benefit them. Students who have not completed units from the VCE Chemistry, Physics, Science or Geology areas of study are advised to consider the PRS in science as a priority. It was intended that the planned PRS Understanding Science unit would motivate the students and generate a high level of interest and be relevant to the students as individuals and to the science ideas taught in primary science school programs.

In designing the unit we considered what had turned students away from science in school and therefore decided not to give them more of the same. Our research identified that one of the main reasons why students have negative attitudes towards science is that they do not feel confident in that area of the curriculum.

As one PRS Understanding Science student wrote in her Personal Record:

> 22nd March 1991. Our aim was to build a model of a water wheel to drive a motor. Well, we did it and it actually worked!!! I don't know why, but I wasn't expecting it to work. It's probably because I haven't done science for so long and I'm still not feeling as confident as I would have been if I had done science right through my secondary school years. I'm glad that the water wheel did work because it has encouraged me to work on and I feel more motivated about the next project.

During the unit the students' ideas, skills and personal experiences will be valued and used to investigate concepts in the environmental and physical sciences. Learning will occur in a supportive environment that encourages open discussion, learning from errors and the development of more positive attitudes toward science. Students will be given the opportunity to research, design and carry out experiments that explore an aspect of science, related to the unit, that particularly interests them.

Participation in the unit encourages students to develop the following attitudes:

- increased interest and involvement in science
- more confidence in their understandings of scientific concepts
- an awareness of the importance of science to their everyday lives
- the realisation of the importance of questioning and challenging ideas
- confidence in expressing their views and contributing to discussion of the physical sciences
- an appreciation of the need for scientific investigation in supporting personal and political decision-making
- valuing the preservation of the environment as a priority in personal decision making.

Assessment.

All Professional Readiness Studies are assessed on an ungraded (Pass/Fail) basis. In the PRS unit students are empowered to take control of their own learning and are accountable for their own learning. Gunstone (1988) in discussing attempts to change students' ideas/beliefs argues that the focus on metacognition (understanding and controlling one's learning) has changed the nature of learning outcomes. He also recognises that students need time to accept the importance of metacognition and that new teaching/learning strategies are required together with new approaches to assessment. Alternative assessment approaches are necessary to reflect the new objectives and to encourage students to seek understanding. The two assessment tasks for this unit include the regular keeping of student reflections in the Personal Record and the Creative Project which encourages creativity and initiative. The Creative Project is a display and a very short student presentation based on it and includes a useful information sheet containing the key ideas and resources. For each of the three topic areas students are expected to construct a model, or design and carry out experimental investigations or analyse a relevant issue to their everyday lives using a literature/media search to design an educational game.

The Personal Record (PR) is a form of journal keeping by students, and encourages them to identify and reflect on their own learning. It is one way to promote improvement in the student's learning. The PR aims to encourage students to become more analytical and reflective about their learning and to value their own role in controlling it. Students are expected to record:

- what they have learned (not what they have done)
- their views concerning a topic
- how they feel about their understandings regarding the concepts
- any change which may occur in their attitudes, beliefs or interests
- answers to questions generated during the unit.

The PR can serve as a mechanism for communication between the student and lecturer. It may act as a vehicle for verbal or written discourse as a means of personal growth and professional development. The Personal Record should become an effective way for students to reflect on their learning, identify misconceptions and any poor learning tendencies, thereby providing a basis for improving learning behaviours and generating changes in attitudes. It is to be hoped that this exploration of the student's own learning will lead to an increase in the student's confidence in science. The PR is similar to an intervention described by Swan and White (1990) which is designed to improve the quality of students' learning by helping primary school children to reflect on their learning by encouraging them to write, each day, one thing they had learned in their 'Thinking Books'. The importance of keeping a journal for enhancing learning has been emphasised by various writers (e.g. Holly, 1984; Ross et al., 1988).

Unit Structure.

The PRS Understanding Science unit was selected by 150 students. It covers scientific ideas drawn from the physical and environmental sciences and includes three topic areas - "Energy for action", "Making the most of modern materials" and "Living with the environment." The focus of investigation in each topic could vary from group to group, depending upon the students' background and interest.

Teaching and learning strategies are varied and include recording and challenging the students' prior views by the use of the P.O.E. (Predict, Observe, Explain) procedure, where students compare their observations with their original ideas and try to explain any differences between the two. For example, 'we have one light bulb connected to a battery, what do you think will occur when we add a second bulb next to it?' (Some alternatives are given) (Note 3). Concept mapping is used to identify links between sessions and to facilitate understanding of concepts.

Co-operative learning in groups enables students to share in the problem solving approach and to listen to and react to other students' views and argue an idea through. Interpretative discussions are used to encourage students to explore their own and others' ideas, to ask questions and judge peer contributions. Presentations, including the Creative Project, provide a mechanism for sharing ideas with the whole group and learning from others. Strategies used are those which have been shown to be successful with females as well as with males. Gender inclusive strategies are important because a significant proportion of the students are female. The emphasis is on 'hands-on' activities, is identified by the research as being important in preparation for effective teaching. The significance of 'hands-on' activities was also highlighted by WASTE (Women and Science Teacher Education Project) (Bearlin et al., 1990) which identified practices affecting attitude change.

Other important teaching strategies include: analysis of data or a story, demonstrations, game playing, guest speakers, individual research, problem solving, role play, values clarification and video.

UNIT EVALUATION

The unit was tried out during semester one, 1991 and evaluated in two ways: firstly by means of the Personal Record (PR) being read and commented on by the lecturer at regular intervals throughout the semester and secondly by students completing a questionnaire at the end of the unit. The PR gives immediate feedback and has been useful for students to monitor their own learning and in turn for the lecturers to monitor the student's progress during the unit and also the relevance of the activities and content of the unit.

Some extracts from the Personal Record of a few students follow.

Student 1. 12th March 1991. We learnt that the understanding science course has three parts - Energy, Domestic Materials and Environmental quality. For each part we are to present a model, experiment or essay. To me this is a good method of learning, instead of taking reams of incomprehensible notes (as in high school) we are made to feel responsible for our particular subject - it becomes our baby and instead of being a chore the learning becomes fun.
16th April. We regrouped for the next section on household chemicals. This time the ideas came quickly whereas last time it took us ages to get an idea for energy, which means that maybe we're starting to get some sort of grip on the subject. I really think that I'm starting to feel a lot more comfortable with science.
3rd May. Today we had a fantastic brainwave. We finally thought of what to do for our Creative Project. For Materials we had already decided to make hand puppets from materials which were appropriate for young children. Then we thought that we would incorporate 'Materials' and the 'Environment' by doing a puppet show where the puppets discuss the 'logging' issue. What a fun way to learn, both for the people doing the research and performing the puppet show and for the audience. We are quite excited about this and hope that our presentation will be very useful. After listening to other people's ideas, it sounds as if the final presentation day is going to be interesting and fun.

Student 2. 25th March. I'm glad that we started with Energy because it is something that we (the students) can relate to and is a part of everybody's lives. I've never studied or looked into this aspect of science before. Previously, I was not interested in science at all, but I now feel that I will enjoy teaching science to young children.
30th April. Science seems to be everywhere, but before this year my view of science was very narrow. I just imagined a scientist in a laboratory. I didn't realise how important science and scientists have been and still are in this world.

Student 3. 15th April. I do know that with each class I learn either - facts on science or I begin to open my mind and see what effects it has on us. Also I can gain new ideas for class structure and what works. I listen to comments from other students such as:

- I thought it would be a cram science course
- It needs more structure
- I like the freedom to develop our projects without pressure.

Student 4. 27th May. This course has really been enjoyable in that it presented topics of modern and pertinent interest. It raised some personal questions of lifestyle and challenged a change. It also encouraged and emphasised a power in change and action to be effective to bring about a positive end. The study of science was encapsulated into a part of everyday life - a study which was both fascinating and interesting.

The second method of evaluation, the questionnaire titled - "My views on the Professional Readiness Study - Understanding Science" was completed by 83 students. Of these, 70% felt that the content was well chosen and 60% found the activities to be challenging. The importance of challenge has been researched extensively by Baird et al. (1990).

The questionnaire also revealed that:

- 51% felt that as a result of taking this unit they were much more highly motivated to teach science; while 45% felt that their enthusiasm was just the same.

- 31% enjoyed learning science a lot this semester, 57% enjoyed it a little and 12% not at all.

- 58% believe that their feelings towards science have changed and are more positive, whilst 29% still felt the same.

- 61% were happy with the amount of choice given for the three areas of the unit.

Although statistical data are not available, observations made during the sessions and subsequent discussion with students, indicate that the PRS Understanding Science unit has succeeded in changing the attitudes and confidence of most mature age students, however, there has been limited change amongst some 18-20 year olds.

Haberman (Note 4), currently developing new forms of teacher preparation based on practice and coaching in the United States of America, recognises the importance of the age of trainee teachers. He believes that "the 18 - 25 year old age group is at exactly the wrong stage of development to be nurturing and understanding the child. We have the wrong people involved in teacher training". His coaching model begins with people usually over 30 years of age and starts when undergraduate courses finish. This PRS unit revealed differences in degree of attitudinal change for the two age groups. It would be useful if further research could be carried out to compare the attitudes of the two age groups, that is, mature age students entering the course with the school leavers direct from VCE.

SUMMARY

The students' evaluation of the Professional Readiness Study - Understanding Science are currently being considered to modify the unit for the next semester. This procedure highlights the importance of ongoing evaluation of the unit, thereby identifying students' views which when responded to, act as catalysts generating change. We believe that this is a useful model for improving courses by making them more relevant for the particular students involved. Overall, the responses indicate that most PRS Understanding Science students have a more positive attitude to science and are enjoying it more. Comments indicate that some students have gained confidence in their own understanding of science and feel more comfortable with the prospect of teaching it. Considering that students were compelled to study a unit that they would not have normally selected and that the time for the study was short - 11 weeks, it is most encouraging to see some evidence of change. A further study of these students' attitudes needs to be undertaken during their second or third year Curriculum and Methodology in Science course, and comparisons made.

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KNOWLEDGE ENGINEERING: AN ALTERNATIVE APPROACH TO CURRICULUM DESIGN FOR SCIENCE EDUCATION AT A DISTANCE

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University of Southern Queensland

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ABSTRACT

Most of the curriculum design models within the technical-scientific approach utilise the rational and sequential process of designing and inter-relating the various elements of the design process. While this procedure may be efficient and adequate for conventional education in which the designers are professional science educators, there is doubt if it satisfies the particular needs of distance education.

The experience accumulated through a multi-disciplinary team approach to distance learning courseware development for higher education at the University of Southern Queensland Distance Education Centre motivated this study which primarily focused on a search for an alternative approach to curriculum development with a more satisfactory functional value.

Using selected units in Engineering as a focus, an experiment was designed in which a variant of the classical Wheeler model was used. This paper reports the results of this experiment. The implications for contemporary curriculum development initiatives in science especially within distance education settings are pointed out.

INTRODUCTION

In a recent comprehensive meta-analytic summary on improving school science, Walberg (1991) evaluated the post-Sputnik science curriculum reforms in, what he called, 'a 30 year retrospective'. Although the reform recorded some measure of success, it met with a number of obstacles which limited the success achieved. For instance, teachers without special training found it difficult to incorporate higher level cognitive questions in their assessment (White & Tisher, 1986), and as Layton (1989) also found, many teachers lack understanding of scientific inquiry or the instructional skill needed for the development of quality courseware.

In general, the development of the new science curricula and associated courseware in most parts of the world, involved amongst many other procedures and groups, the formation of writing teams of specialists (which include science educators and teachers) and the training of teachers in new content and methods (Tamir, 1989). While the participation of teachers in the development of curricula has received support on philosophical and pragmatic grounds (Carson, 1984; Doyle & Porter, 1977; Fullan and Pomfret, 1977) no empirical evidence is available to justify it. Indeed Young (1989) and Chung (1985) reported that not all teachers find participation attractive. This situation pertains to secondary school science curriculum development where there is the probably unjustifiable assumption that teachers involved in development have professional competency relating to curriculum design as well as psychological foundations of learning. Such comments on teacher participation are relevant to situations where the instructional curriculum materials are designed for use in a conventional situation of face-to-face instruction. There are, of course, other situations that are quite different. For example, developing curriculum materials for instructional purposes for higher education within a distance education setting. In this context it is not unusual for a number of the teachers participating in the development of the materials to have neither the professional competence nor the orientation in curriculum engineering, since teachers in higher education are often appointed primarily for their subject matter expertise. Many teaching staff in higher education institutions have little or no formal training in curriculum-instructional design. If even in supposedly ideal situations outcomes are far from the expected, the results can be imagined in a non-conventional mode of instruction in which some teachers participating in the development of curriculum materials are professionally unprepared. In this situation therefore the role of the instructional designer can be onerous and demanding.

DISTANCE EDUCATION AND COURSEWARE DESIGN AND DEVELOPMENT

Distance education, which has gained ground within the past two decades, is significantly different from conventional education. A detailed discussion of the differences is beyond the scope of this paper. However, some of the salient and pertinent differences are as follows:

- In distance education, the act of learning is separated from the act of teaching (Keegan, 1980).
- Distance education has more complex management requirements reflecting greater challenges in planning, organisation, control and measurement while the most important locus of management is the classroom in conventional education (Daniel & Stroud, 1987).
- Distance education is an industrial operation involving design, production, delivery and servicing with a management consortium whereas in conventional education the key managers are the individual teachers.
- The skills required in conventional and distance education teaching modes are different and varied. A competent teacher in a conventional classroom may not necessarily be a good distance education teacher (Baath, 1981).
- In distance education, the organisational, pedagogical and outcome contexts of learning are dependent on the effective design of materials.
- Instructional design in distance education is often undertaken by a team and is based on the philosophical underpinning of relating ideas in learning theories with educational practice. In contrast instructional design (e.g. preparation of lecture notes) in conventional education is undertaken individually by lecturers who in the main are totally unaware of, or unperturbed by learning theories, educational practices or curriculum design.

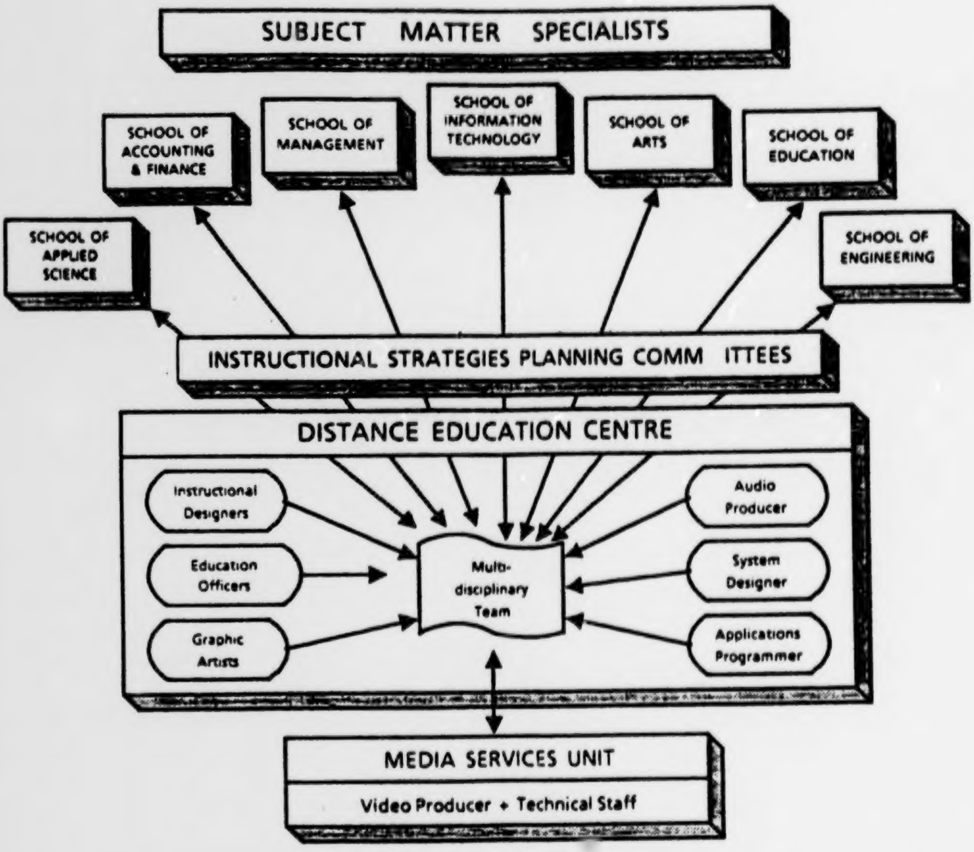
Courseware production for higher education instruction often involves the elements of design, development, production and delivery utilising a multi-disciplinary team approach technique. Although variations may occur depending on institutions and the scope and intensity of interaction within the team may differ, the basic procedure and the elements of courseware production are universally the same.

The University of Southern Queensland Distance Education Centre's approach to courseware development, tested over a long period of time, follows a multi-disciplinary team approach (Figure 1) referred to locally as a "Unit Team". A Unit Team consists of a Team Leader (the lecturer responsible for the content), an Instructional Designer, an Education Officer and media specialists (audio-visual, graphic design, computing) as required (Figure 1). The unit team prepares the instructional blueprint, decides on the issue of media mix, copyright, procedures associated with CAL, CML, audio and video tapes, teletutorials, residential schools, computer access etc. The team meets regularly in the design phase and monthly to monitor development after the sample module has been produced. The initial design of a unit framework or blueprint by the Unit Team is subjected to a review by the Instructional Strategies Planning Committee based in each of the Teaching Schools.

The unit team leader and the instructional designer are central to the design and development of an instructional unit (a unit is approximately a 140-hour course taken by a distance learner in a semester). The unit team leader who provides the content of the unit is usually the expert academic staff member teaching the course on-campus to full time students. In most cases, the lecturer may not have heard about instructional design and curriculum development, learning theories etc. She/he may also be under the mistaken impression, particularly if this is the first involvement with distance education, that the normal lecture notes used on-campus with a little bit of addition and editing here and there would transform into a distance learning material. This is where the role and function of the instructional designer becomes germane.

The instructional designer, usually a professional educator specialised in the discipline of instructional design, brings into the unit team the expertise of curriculum engineering. The design and development of a blueprint for the whole instructional package using a curriculum model, usually leads to the documentation of the knowledge base, consisting of both declarative and procedural knowledge, and the elaboration of the sequence of presentation using a model of human information processing as a framework. (Taylor & Evans, 1985). While the instructional designer does not question the academic content of the unit (indeed she/he might not in fact have any idea about the subject matter), she/he asks the lecturer questions relating to unit and module objectives, how they relate to content and if assessment questions match stated objectives. Experience and evidence in the literature show that if learners' performances are measured against clearly stated sets of criteria as contained in instructional objectives, their attitude and achievement will improve (Brinkley, Pavlechko & Thompson, 1991).

But in courseware development not many content experts could sufficiently discern the goals, modality of achieving the stated goals and the ability to determine effectively if the goals have been reached. The issues therefore are: How does an instructional designer orientate the content expert member of a unit team towards appreciating and using curriculum and instructional design models as a basis for courseware development? What model of curriculum design and development would be appropriate for use by the unit team? How does an instructional designer relate the interactions between the curriculum design elements with the practical development of a unit curriculum material in a situation in which the unit team leader may not have


SUBJECT MATTER SPECIALISTS
SCHOOL OF ACCOUNTING & FINANCE
SCHOOL OF MANAGEMENT
SCHOOL OF INFORMATION TECHNOLOGY
SCHOOL OF ARTS
SCHOOL OF EDUCATION
SCHOOL OF APPLIED SCIENCE
SCHOOL OF ENGINEERING
INSTRUCTIONAL STRATEGIES PLANNING COMMITTEES
DISTANCE EDUCATION CENTRE
Instructional Designers
Education Officers
Graphic Artists
Multi-disciplinary Team
Audio Producer
System Designer
Applications Programmer
MEDIA SERVICES UNIT
Video Producer + Technical Staff

Design	Instructional Designer + Subject Matter Expert(s) + Education Officer	1. Generate a detailed instructional development blueprint. 2. Prepare a timeline for the project.
Development	Instructional Designer	1. Train the subject matter expert(s) to use the blueprint for development. 2. Coordinate the production of learning materials.
	Education Officer	1. Provide administrative support to the unit team. 2. Implement procedures associated with maintenance of data bases (unit specification, assignment, CML, mailing), residential school, telephone tutorials, copyright, etc.
	Subject Matter Expert(s)	1. Produce learning materials, (written instruction, self-assessment questions, scripts, CML, etc.) according to the instructional blueprint.
	Media Specialist(s) • audio-visual • computing • graphics	1. Produce learning materials according to prescribed medium and design.
Evaluation	Total Development Team	1. Review and revise learning materials.

Fig. 1: Overview of the Organisational Structure for the Preparation of Instructional Materials (USO).

had formal training as a professional educator? These practical questions which surface perennially in the courseware development management at the University of Southern Queensland Distance Education Centre were used as research questions in the determination of an efficacious model capable of meeting the particular needs of a unit team. This exploratory study was undertaken to seek answers to these questions.

THE EXPERIMENT

Most of the subject-centered curriculum development models lean towards a technical-scientific approach to curriculum development. According to Ornstein and Hunkins (1988) this is the major approach to curriculum creation today. This approach embraces the rational (Tyler-type), critical (Wheeler) and dynamic (Walker) models of curriculum design (Print, 1987). The two major characteristics of these models, (i.e rational and sequential), give the approach a negative connotation of rigidity even when proponents profess the opposite. This is further compounded by the fact that no consensus about the relationships between curriculum elements, their order and exact nature has been reached amongst experts. As supported by recent reviews (Frey, Frie & Langeheine, 1989; Searles, 1981), no reported studies have tested the effects of the various developmental models on curricula nor attempted to refute the general assumption concerning the simplication of the nature of curriculum process.

The need for the study became obvious when, in addition to the theoretical issues outlined above, unit teams constantly reported problems with the use of the generalised cyclical model of Wheeler, particularly when the lecturer in the team had no formal training in curriculum design and development. Two units from Engineering were chosen as target trials for the study and the technical-scientific approach, which is seen to exhibit technological rationality (Macdonald, 1975), was adopted.

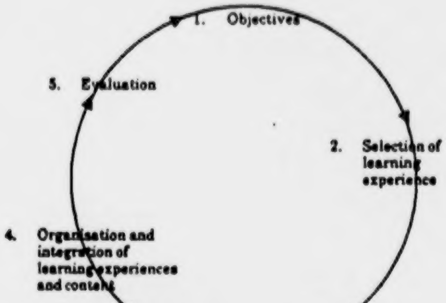

1. Objectives
2. Selection of learning experience
3. Selection of content
4. Organisation and integration of learning experiences and content
5. Evaluation

Fig. 2a. The Wheeler Model

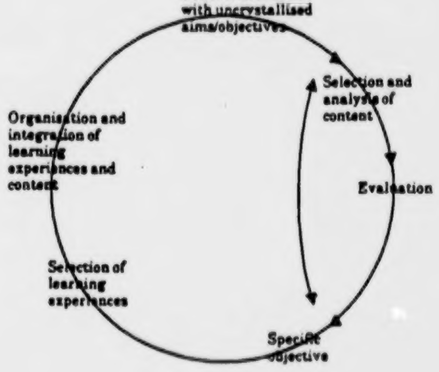

Generalised focus with uncrystallised aims/objectives
Selection and analysis of content
Evaluation
Specific objective
Selection of learning experiences
Organisation and integration of learning experiences and content

Fig. 2b. The New Model

Test of the Model

In the design of the Engineering units, the instructional designer (one of the authors) used a model which began with an outline of the topics and objectives of the unit as specified for course accreditation procedures. The model differs from the generalised Wheeler model (Fig. 2a) in several respects. For instance, it begins with the selection and analysis of the unit content in relation to the hazy and often uncrystallised ideas and objectives and the type and structure of the evaluation of the unit (Fig. 2b). Secondly, these ideas are used in the cooperative formulation of the specific objectives of the unit and subsequently used as the basis for refining the content selected (cf. Fig. 2b). The analysis of content and its representation in terms of a knowledge base consisting of relational and strategic knowledge (Taylor & Evans, 1985) is exemplified in Fig. 3. A detailed discussion of the psychological underpinnings of this framework (Taylor, 1983) is beyond the scope of this paper, but the outcomes of the approach suggest that this level of elaboration of content goes well beyond that used typically in preparing higher education courses for delivery in the conventional face-to-face mode. Such a level of analysis provides a solid foundation for making decisions about the appropriate media-mix for the unit. Such decisions about the use of computer based approaches, the use of audiotapes and/or videotapes and the extent to which print-based resources should be developed need to be informed by a number of other considerations (Taylor & Barker, 1990), not the least of which is the assessment methods to be implemented in light of specific instructional objectives. Once the team leader had delineated the detailed structure of the content, the instructional designer proceeded from content to assessment. The specific objectives could then be derived from the detailed assessment (assignments, examination questions etc.) at which point the lecturer was asked to look at the content again to ensure consistency between content, assessment and objectives. This led to the discussion of the learning experiences necessary for learners to develop the knowledge and skills to be assessed. Thus development of the courseware according to the detailed design specification (instructional blueprint) in an organised and integrated manner could then proceed. The process was applied at a general level to the unit as a whole and then to each of the modules in turn.

The major idea behind the use of this model was that lecturers, who do not have any formal training in curriculum design and development, are often not interested in starting with the specification of objectives and subsequently matching test questions to these pre-specified objectives. Lecturers are, however, very positive about the analysis of content, which taps their specialist expertise in a specific subject matter domain. The representation of the knowledge base appears to provide an effective and productive starting point as a means to involving lecturers in courseware design and development, whereas strict adherence to the classical Wheeler or Tylerian model of curriculum design has often proved to be ineffectual. This is in contrast to the usual process entailing the rational progression in a sequential manner from situational analysis to objectives through content and learning experiences to evaluation.

Qualitative Analysis

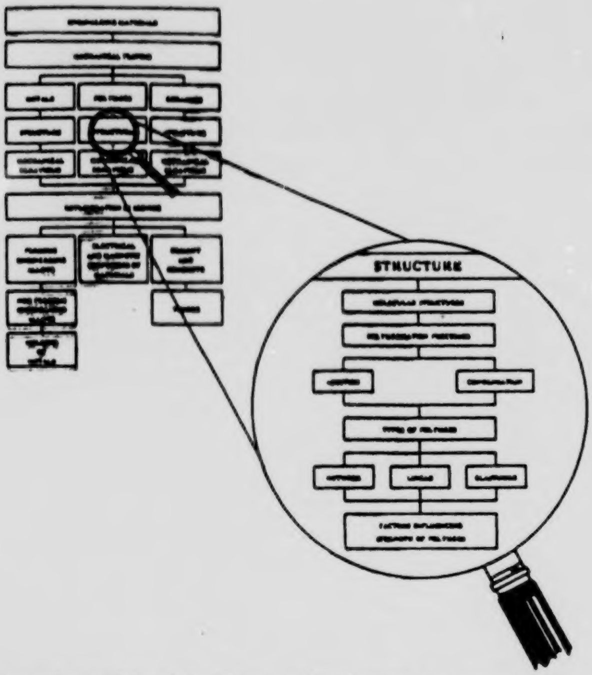
The analysis of the whole process was qualitative as quantification of behaviour in the context of the study was obviously inappropriate. The assessment of the whole trial was multifaceted and included: (a) instructional designer-prompted lecturer assessment of personal progress and satisfaction with the writing of the materials using the 'new' model, (b) anecdotal reports of the instructional designer, taken at each meeting with the lecturers, (c) the validity of the materials produced in relation to the various aspects (e.g. objectives, content, assessment details, assignment etc.); and, (d) the general assessment, comments and views of other members of the design and development team.

FINDINGS

A synthesis of all the reports and analyses revealed that as opposed to the classical Wheeler (1971) model of curriculum design (Fig. 2a) the model used in this study (see Fig. 2b) was very effective and successful in not only making the lecturers appreciate, and learn to use, the curriculum design model but also in the subsequent design and development of high quality materials. The analysis outlined in Figures 2 and 3 was subsequently incorporated into the instructional materials. It also helped in engendering a user friendly atmosphere for the use of a curriculum model as a basis for instructional design without threatening the credibility of the lecturers as professional educators. The results of the study also revealed that pedagogical knowledge and knowledge about curriculum design might be a limiting factor in curriculum engineering for distance education. The new perspectives on teaching and learning achieved by the lecturers greatly improved their courseware development capabilities and, according to unsolicited personal testimonies, also enhanced their teaching of full time on-campus students. Further, it was evident that working relations among unit team members were more cordial once the lecturers understood that the use of the elements of the curriculum design process did not depart markedly from the way they normally looked at teaching, as an expression of subject matter expertise.

IMPLICATIONS AND CONCLUSIONS

Due to the exploratory nature of the study, we recommend that caution be exercised in the interpretation of the results or the adoption and use of the major findings. However, within the limits of its validity, several implications of the results should be borne in mind. First, the success met as a result of the use of the 'new' knowledge engineering model seems to indicate that empirical results could be obtained to test the effects of developmental models (Frey, Frei & Langheine, 1989). Second, within the distance education context, and particularly where most of the lecturers who develop curriculum materials are non-professional educators, the use of the classical Wheeler model might not be suitable. Third, the use of the multi-disciplinary unit team approach to instructional design seems very effective. It fosters cooperative development, promotes purposeful peer group interaction that leads to a meaningful exchange of ideas, and it serves as a good platform for the efficient professional use of instructional designers. Fourth, it does appear to have the potential to make a significant contribution to the field of higher education, in which due to its nature and organisation, neither a concerted effort nor a well mapped out procedure for curriculum design and development is available. There is a need to take another look at this with a view to rectifying the problems of teacher participation and expertise in curriculum design and development in higher education. Lastly, there is a need for a replication of this study so that the knowledge engineering model can be subject to further empirical validation for a categorical determination of its efficacy across a wide range of disciplines.



The complete strategic model for solving this type of problem and the particular path used to find the solution in this case are shown below.

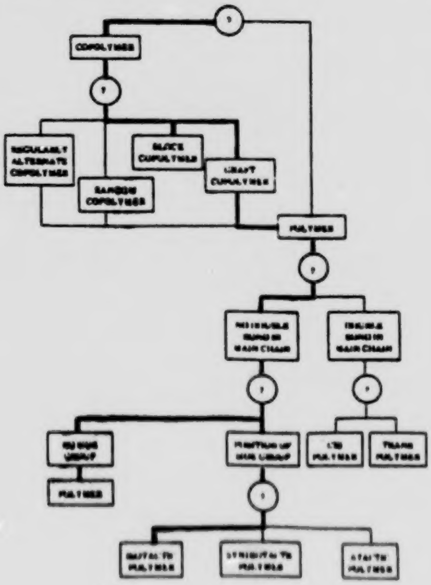

COPOLYMERS
REGULARLY ALTERNATE COPOLYMERS
BLOCK COPOLYMERS
GRAFT COPOLYMERS
RANDOM COPOLYMERS
POLYMER
NO DOUBLE BONDS IN MAIN CHAIN
DOUBLE BONDS IN MAIN CHAIN
NO SIDE GROUP
POSITION OF SIDE GROUP
CIS POLYMER
TRANS POLYMER
POLYMER
ISOTACTIC POLYMER
SYNDIOTACTIC POLYMER
ATACTIC POLYMER

Fig. 3 Relational and strategic knowledge representation.

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A COMPARISON OF ELEMENTARY TEACHER ATTITUDES AND SKILLS IN TEACHING SCIENCE IN AUSTRALIA AND THE UNITED STATES

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ABSTRACT

A study, originally done in Australia in 1983, was replicated in an urban-suburb in the United States. The Australian project involved matched pairs of year-five teachers in one of two workshops. One workshop taught the skills of teaching electricity, while the other one discussed issues in gender equity in science education (active participation of both girls and boys, comparable student-teacher interactions, and research findings concerning equity). The U.S. study provided three types of workshops (skills, equity and skills, and equity) for comparable groups of fourth and fifth grade teachers. All teachers and their students were subsequently observed during lessons involving an electricity unit. In addition, questionnaires, given before and after the electricity unit, queried both students and teachers concerning the appropriateness of different fields of science for boys and girls and their interest and aptitudes in doing various types of science. Results from both studies suggest that gender differences in student attitudes toward science may be amellorated by specific types of teacher workshop.

INTRODUCTION

At present, relatively little is known about the actual practices and perceptions of elementary school teachers as they go about the work of teaching science (Gallagher, 1989). What is known is that many elementary teachers determine the goals pursued in their classrooms, that they decide the content and instructional strategies used, and that they maintain considerable autonomy in the way science is taught.

Research shows that elementary school teachers, who are primarily women, prefer to teach certain science topics. When U.S. elementary teachers are asked to name a specific science area that they would find difficult to teach, 63% identify physical science, 21% select earth science, and 7% choose life science topics (Horizon Research, 1989). That pattern of teacher preference is mirrored in the interest and achievement differences found between elementary girls and boys. For example, Harlen's (1985) work in the United Kingdom indicates that by age 11, girls, compared with boys, show more interest in nature study and less interest in physical science topics. Likewise, Kahle and Lakes (1983) show that, compared with boys, 9-year-old girls are more likely to have cared for an animal or plant but less likely to have tried to fix something mechanical or electrical in school science. In Israel, girls typically perform least well in the physical sciences, especially in physics, while they perform as well as boys do in the biological sciences (Levin, Sabar & Libman, 1991).

Based on her review of European initiatives for encouraging girls into science and technology, Whyte (1984) concluded that few studies had directly evaluated the effect of teachers' attitudes and expectations on boys' and girls' interest and achievement levels in science. However, a project by Rennie, Parker and Hutchinson (1985) in

Western Australia evaluated teacher perceptions of boys' and girls' self-confidence, interest, and performance levels in science as well as their ease of understanding of various science topics. Through the use of inservice workshops, they addressed both perceived gender-differences as well as the teachers' lack of background knowledge and skill in teaching physical science. Recently, that study was replicated in the U.S.

DESIGN OF THE STUDIES

Both studies were conducted in large metropolitan areas in schools that enrolled students primarily from lower-middle to middle class families. Both projects focused on upper elementary school (grades 4-5). Both drew their teacher samples from several schools, and both addressed change in the teachers while assessing the impact of that change on students. In both studies the topic of electricity served as the science skill topic, and both projects used teacher inservice workshops as the mode of intervention. Approval for both projects was obtained from central administration, indicating community interest and administrative support. Despite these similarities, both major and minor adjustments were made in order to replicate the study across time and cultures.

Major differences, beyond the control of the researchers, included differences in the racial make-up of the student sample and in the ratio of female to male teachers. The Australian student sample was Caucasian, while minority students (primarily African-Americans) comprised 48% of the U.S. sample. In the Australian teacher sample there were 9 women and 9 men, but only 5 male teachers (out of 26) were included in the U.S. study. The U.S. study expanded the experimental design to include a third experimental group and a retention component. Two minor changes involved the way participants were divided into groups and the division of science content areas in the questionnaires. The Australian study was conducted in 1983, while the U.S. study was conducted seven years later in 1990-1991.

The experimental design of the Australian study matched fifth grade teachers by sex, background, and experience. Members of the matched pairs, then, were randomly assigned to one of two groups. The control group (8 teachers) participated in a half-day workshop involving skills in teaching electricity. The experimental group (10 teachers) participated in the same half-day workshop plus an additional day-and-a-half workshop which concerned equity issues. A total of 394 boys and 373 girls were taught by those teachers.

The experimental design of the U.S. study matched school groups of teachers by background and experience into three treatment groups. Teachers participated in one of three workshops: skills in teaching electricity, (8 teachers) skills in teaching electricity plus equity (9), and equity only (9). All workshops were a full day and were followed by a second half-day. There were a total of 315 girls and 354 boys in their classes. The third experimental group was added to the U.S. study in order to assess whether equity training alone, independent of content skills, would change the way that teachers taught science and result in improved student attitudes toward science.

RESULTS

Background Information

Teachers participating in the U.S. and Australian studies, had similar educational backgrounds and teaching experiences. All of the U.S. teachers surveyed held baccalaureate degrees in elementary education and teaching certificates. Over half had earned advanced degrees in education, specializing in curriculum and supervision, elementary education, reading, school administration, or speech pathology; 84% had over four years of teaching experience. All the Australian teachers held three-year teaching qualifications, or the equivalent, and three-quarters of them had worked toward a higher qualification, usually a Bachelor of Education degree; 93% had over five years teaching experience. Two teachers in the Australian sample, none of the Americans had been a science major.

Although the science curriculum taught in both countries was similar, the availability of resources to teach science differed. The U.S. teachers rated their resources as "less than adequate" in all areas, while the Australian teachers responded that their resources were "just adequate".

Teachers were asked to estimate how frequently each of nine kinds of activities occurred in their science lessons. Approximately half of the U.S. teachers responded that over 50% of the time they led discussions or explained content. However, Australian teachers indicated a more varied approach to teaching science. The following activities were ranked equally high by the Australian group: "children do teacher directed activity", "teacher leads discussion", "teacher explains content", and "children do own activity."

Instruments

Two questionnaires developed by Rennie et al. (1985) were used to collect the data. Both used primarily a closed-response format with opportunities for respondents to write in other points. The teacher questionnaire contained 44 items which assessed teacher knowledge, interest, and skill in teaching science as well as perceptions about the performance, interest, ease, confidence, and relevance of various science topics for girls and boys. Because of differences in the U.S. and Australian curricula, a change was made in the categories to which the teachers responded. In Australia only two areas were presented (biological and physical science); each had two common topics listed (animals and plants and matter and energy). On the questionnaires used in the U.S., three categories (biological, earth and physical science) were listed. Each of which included two sample topics (animals and plants, astronomy and geology, and matter and energy).

The student questionnaire probed student interest and self-confidence in doing a variety of science lessons as well as student attitudes toward various content areas in science. Because this paper focuses on teacher attitude and skills, results from only one item from the children's questionnaire are reported here. All items on both questionnaires used a Likert-type response format, which ranged from high (positive attitude, interest, relevance, etc.) to low (negative attitude, etc.). Most responses were scored on a scale from 5 to 1, but items assessing teacher skill and background knowledge as well as the availability of teaching resources used a 3 point scale.

Background Knowledge and Skill in Teaching Different Areas of Science

U.S. teachers were significantly more interested in teaching topics in biology, followed by topics in earth science, than they were in teaching physical science topics,($F=20.71$ $p<0.001$) However, significant differences were not found in the interest expressed for biological or physical topics by male or female Australian teachers. Gender comparisons were not possible in the U.S. sample because of the small number of male teachers.

When teachers were queried about the adequacy of their background in various science areas, significant differences were found. U.S. teachers thought that they had significantly more background knowledge about biological topics than they had for physical and earth science topics ($F=7.57$, $p< 0.001$). Although both male and female Australian teachers indicated that they had adequate knowledge to teach lessons about animals and plants, significantly more male, teachers thought that they were adequately prepared to teach the topics of matter and energy ($p< 0.05$).

Teachers were asked also to rate their skill in teaching topics in several science areas. Again, significant differences were found. American teachers rated themselves significantly more skilled in teaching biological topics than they were in teaching earth or physical science topics ($F=16.61$, $p<0.0001$). Both male and female Australian teachers ranked themselves as skilled in teaching topics about animals, plants, and matter, but significantly more male Australian teachers ranked themselves skilled in teaching the topic of energy ($p<0.05$).

Reasons for Teaching Science

Teachers were asked also to rate each of eleven suggested reasons for teaching science according to "how much importance does your science teaching and programming give to each of these considerations in teaching science to children?" The rankings are displayed in Table 1. Both groups of teachers responded that the most important reason for teaching science was "to interest students in science". They also concurred that "to give practice in problem solving skills" was an important reason for teaching science. However, wide differences were found in the rankings of the following two reasons: "to provide scientific knowledge" and "to prepare students for science later on."

TABLE 1
AUSTRALIAN AND U.S. RANKINGS OF REASONS FOR TEACHING SCIENCE

REASONS	Rank: Australia	Rank: U.S.
to interest children in science	1	1
to give practice in problem solving skills	2	4
to show how science is related to everyday life	3	2
to develop self discipline and independence	4	7
to give practice in communication skills-verbal	5	9
to develop social skills (such as cooperation)	6	8
to give practice in communication skills-written	7	11
to integrate science with other school subjects	8	6
to provide scientific knowledge	9	3
to give practice in manipulative skills	10	10
to prepare students for science later on.	11	4

Teachers' Perceptions Concerning Science for Girls and Boys

For each topic or area of science, teachers were asked to indicate the relevance and ease of that topic for girls and for boys. No significant differences or interaction effects were found. Both U.S. and Australian teachers perceived all topics or areas of science to be equally useful and relevant to girls and boys.

Teachers were also asked to indicate children's level of understanding for each area of science. U.S. teachers perceived physical science topics, followed by earth science topics, to be the most difficult. They rated biological science topics as the easiest ones for all children. ($F = 37.74$, $p < 0.0001$). When the data were analyzed by sex, U.S. teachers responded that girls and boys had equal levels of understanding across the science areas. Furthermore, significant interaction affects were not found for U.S. teachers' responses. Although both men and women Australian teachers responded that boys and girls had comparable levels of understanding about plant and animal topics, female Australian teachers thought that the topics of matter and energy were more difficult for girls than they were for boys ($p<0.01$).

Teachers were presented with statements of behavior reflecting children's self-confidence, interest, and performance levels in science. U.S. teachers perceived students to be significantly more confident of their ability to learn biological topics than they were to learn topics in either physical or earth science. When the data were analyzed by student sex, the U.S. teachers indicated a consistent and significant difference between boys and girls across content areas, ($F = 17.07$, $p < 0.0001$). The Australian teachers, however, responded that the girls' confidence, compared with that of boys, was significantly lower for physical science topics (female teachers $t = 3.71$, $p < 0.01$; male teachers $t = 2.92$, $p < 0.01$).

Teachers also responded to items that assessed their perceptions of children's interest in various areas of science. U.S. teachers perceived students to be significantly more interested in biological topics than they were in physical and earth science ones($F=24.32$,$p<0.0001$). Girls were consistently perceived by the U.S. teachers to be significantly less interested in all of the science areas than boys ($F = 7.77$, $p < 0.005$). Australian teachers perceived girls to be less interested than boys were in physical science topics ($t = 3.11$, $p < 0.01$), but they perceived boys and girls to be equally interested in biological topics.

Teachers also responded to questions about the performance of girls and boys in lessons/activities in various topics in science. U.S. teachers responded that all students performed significantly better in biological science than they did in physical and earth science ($F=7.39$,$p<0.001$). Furthermore, U.S. teachers did not perceive sex differences in performances across the content areas, and no significant interaction effects were found. On the other hand, Australian male and female teachers responded that girls, compared with boys, performed better in biological science ($t = 6.18$, $p < 0.01$).

Children's Questionnaire

Prior to the intervention workshops in both studies, children were asked, "If you wanted to, could you become a scientist?" Shortly after the completion of the electricity unit, they were asked, "If you wanted to, could you become an electrician?" Their responses provided one measure of the efficacy of the workshops in changing students' attitudes. about science.

Mean gain scores by group were analysed for gender effects. The Australian study indicated a higher number of affirmative responses after the workshop from the skills/equity sample than from the skills only sample (F=3.90, p<.10). Furthermore, gender and workshop type interacted to influence responses (F=7.24, p<.05). That is, the difference between the number of boys and girls responding affirmatively was smaller for the students in the skills/equity group than in the skills only group. Ninety percent of the boys in both treatment groups thought they could become electricians, while more girls in the skills/equity group (85%) responded affirmatively than did girls in the skills only group (70%).

Responses from the U.S. study indicated that almost all students responded 'yes' to the electrician question regardless of which workshop was taken by their teacher (Fig.1.) For example, 93% of both boys and girls in the skills/equity group thought they could become electricians. This illustrated a 24% increase for boys and a 28% increase for girls (Fig.2). In comparison, 91% of the U.S. boys and 88% of the girls in the skills only group thought they could become electricians. This illustrated a 15% increase for the boys and 24% for the girls (Fig.2). Finally, 88% of the U.S. boys and 90% of the U.S. girls in the equity group (a condition not included in the Australian study) thought they could become electricians. Furthermore, there was a significant increase in the number of girls who thought they could become scientists/electricians in that group (Chi square = 10.69, p<.005). The proportion of girls who responded 'yes' increased 35% while the proportion of positive answers from boys increased only 12% (Fig.2).

DISCUSSION AND SUMMARY

The results of the teacher questionnaires revealed similarities between Australian and U.S. elementary science teachers and programs. In addition, similar sex-role stereotypes were revealed when both sets of teachers were queried about girls' and boys' confidence, performance and interest in various areas of science.

Teachers in both countries rated their preference, skill, and interest in teaching physical science topics lowest among the content areas. In addition, the U.S. teachers, who stated that their resources in all science areas were inadequate, rated the availability of materials and equipment to do physical science the lowest. Lack of equipment and materials in the U.S. classrooms may have been related to their use of more teacher-directed activities (lecture and structured discussions). Classroom observations corroborated the prevalence of teacher-directed instruction in the U.S.

In spite of differences in instructional techniques, teachers in both countries held similar beliefs about teaching science. Both groups ranked "to interest children in science" and "to give practice in problem solving skills" high among the eleven suggested reasons for teaching science. However, the impact of competency-based testing as well as publicity about U.S. students' low achievement levels on both national and international science tests may have caused U.S. teachers to rank "to prepare students for science later on" and "to provide scientific knowledge" much higher than their Australian counterparts did. In addition, those goals are compatible with the style of teaching used; that is, teacher-directed instruction. U.S. teachers' practice of science closely parallels their stated reasons for teaching science.

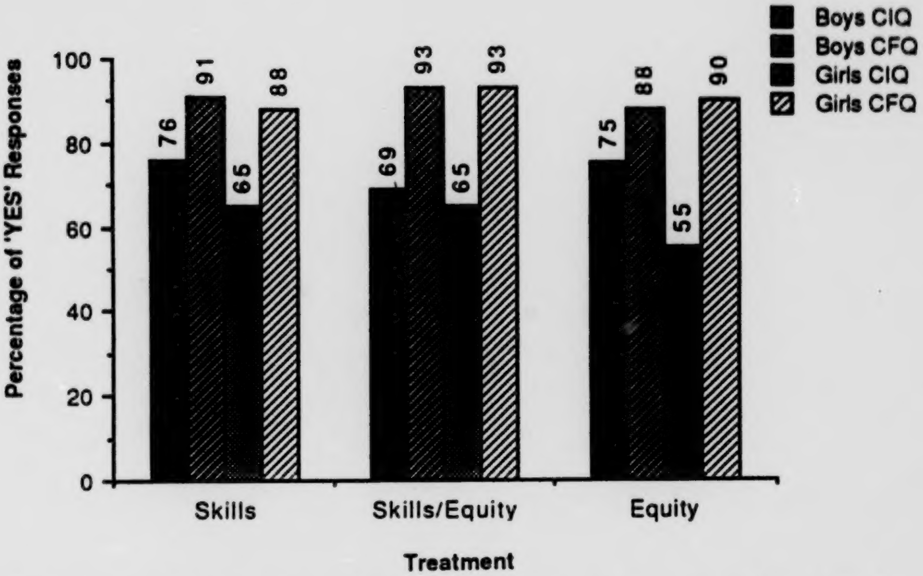

Fig. 1 Percentage of Boys' and Girls' Pre and Post Test 'Yes' Responses by Treatment Groups "Could You be a Scientist/Electrician?"

CIQ = Children's Initial Questionnaire (Could you be a scientist?)

CFQ = Children's Final Questionnaire (Could you be an electrician?)

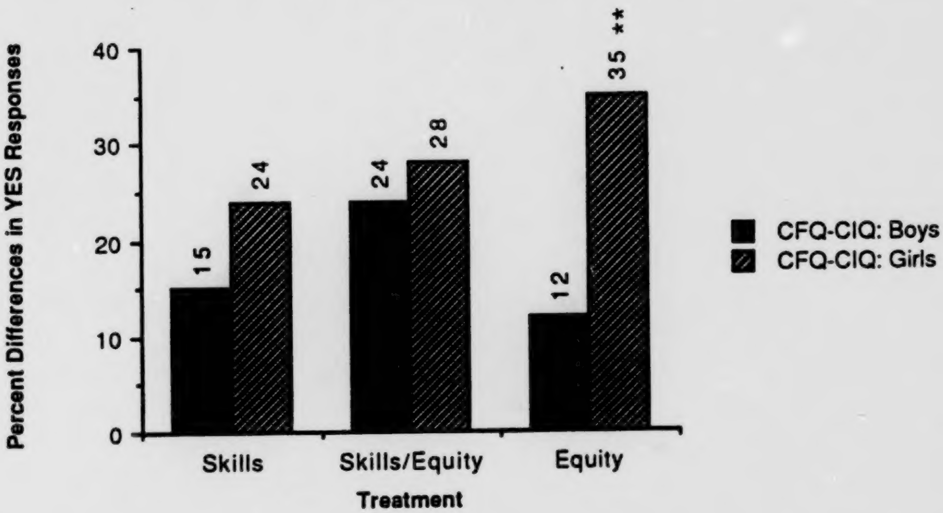

Fig. 2 Percentage in Boys' and Girls' Pre and Post Test Responses (Gain Scores) by Treatment Groups "Could you be a Scientist/Electrician?"

** p< .005 (for chi square)

CIQ = Children's Initial Questionnaire (Could you be a scientist?)

CFQ = Children's Final Questionnaire (Could you be an electrician)

Because both projects were based upon concern for equitable science education, the gender-related responses of teachers concerning the children's confidence and interest in science as well as the relevance and level of understanding of science for girls and boys were of special interest. Although the questionnaires were distributed seven years apart on two widely separated continents, the responses were remarkably similar. For example, both groups of teachers responded that all areas of science were relevant for all children. Although U.S. teachers thought that girls, compared to boys, were less confident in all areas of science, Australian teachers perceived that difference only in physical science. U.S. teachers responded that both boys and girls performed less well in physical and earth, compared to biological, science. Australian teachers, on the other hand, believed that girls performed significantly better than boys did in the biological sciences. When teachers were queried about boys and girls interest in science, Australians again separated the children by sex only in physical science. They thought that girls were significantly less interested than boys were in physical science. However, the U.S. sample responded that girls, compared to boys, were significantly less interested in all areas of science. The consistent stereotyping of biology as a subject for girls, and physical science as one for boys, found among Australian teachers, was not found in the U.S. sample. In the U.S., gender differences in self-confidence and interest were extended to all areas of science.

When one relates teachers' perceptions about science for girls and boys to their own attitudes about teaching science, a pattern emerges. Both the Australian female teachers and the overwhelmingly female sample of U.S. teachers stated that they were less skilled and had inadequate knowledge to teach physical science. They also perceived the girls in their classes as less interested and less confident in physical science. According to Eccles' (1987) psycho-social theory of gender-related differences, teachers are powerful socializers who may transmit their biases and concerns to students, particularly to same-sex students. Therefore, it is particularly important for intervention programs to change the gender-role stereotypes about science that are held by many women teachers.

In both projects, changes in teachers were assessed by changes in their students, and both projects demonstrated the efficiency of short-term workshops that presented equity information as well as the skills of teaching science together (Australia and US) or alone (US). Significantly more US and Australian girls, taught by teachers with equity training, gained confidence and interest in doing physical science, specifically in becoming an electrician.

Our findings suggest the resiliency and prevalence of gender-role stereotypes held by teachers and the similarity between teacher beliefs about science and their gender-specific perceptions of children's understanding, confidence, interest, and performance in science. Fortunately, teacher intervention projects that specifically address equity issues seem to modify teacher behavior in ways that enhance girls' levels of confidence in doing science.

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THE GRADUATE DIPLOMA IN PHYSICS AND EDUCATION: A TEACHER TRAINING INITIATIVE

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ABSTRACT

In Victoria, students intending to become physics teachers must choose to study physics in the final two years of high school, and then for at least two years at tertiary level. For those who have not taken this route there has been little access to the study of physics at a tertiary level and to a career in physics teaching. The Graduate Diploma in Physics and Education at La Trobe University offers graduates who have not studied physics as part of their undergraduate degree an opportunity to train as physics teachers.

Implementation of the diploma has entailed a re-examination of the content and teaching style of undergraduate physics. In this paper, the course structure as a whole will be outlined and the physics taught as part of the diploma described. The preliminary results of the on-going course evaluation will be presented.

INTRODUCTION

The last decade has seen in Victoria a significant decrease in the number of appropriately qualified graduates who have elected to become physics teachers. This has led to a significant shortfall in the supply of qualified physical science teachers in Victorian secondary schools (Victorian Government, 1987). In part this shortfall reflects the strong demand for science graduates from areas other than teaching which offer more attractive careers. However, this shortfall may also be regarded as a result of the structures within physics education, which effectively demand that in order to be a physics teacher one must study physics continuously through four years of formal education, and offer little opportunity of entry to an individual who has not chosen the traditional path. Graduates who wish to become teachers, but who lack the appropriate training in physics, have had few opportunities to gain this expertise.

The Graduate Diploma in Physics and Education at La Trobe University offers to tertiary graduates who may never before have studied physics the opportunity to train as physics teachers. It is a joint initiative of the School of Education and Department of Physics at La Trobe University. Seeding funding for an initial three years has been provided by the Victorian Education Foundation, which is an organisation which funds projects which link education with industry, or which may contribute to the economic advancement of the state of Victoria.

The Victorian Ministry of Education requires that in order to teach a subject at year twelve in a secondary school one must have studied that subject for at least two years at tertiary level. Thus, for example, a person who possesses a B.A. degree, and who has studied history at both first and second year level is qualified, upon completion of a Diploma in Education with appropriate teaching practice, to teach history up to year twelve. Usually, entry to Diploma in Education courses is restricted to those whose degrees enable them to offer two (or more) teaching methods. In order to gain entry to the Graduate Diploma in Physics and Education candidates must possess a degree which offers them one teaching method. They must also have studied mathematics to year twelve. At present, of the ten students enrolled in the course, four have a B.Sc. in Biological Sciences, two have a degree in Applied Science, and four have a Bachelor of Arts. The arts graduates have majors in history, philosophy, politics and psychology. All of these students have gained a first degree, and thus may be regarded as mature age students: at least four out of the ten have returned to study after a significant break during which they participated in paid employment or undertook other work.

In order to gain this qualification students are required to undertake two years of full time study. During this time they complete a Diploma in Education with physics as one of their two teaching methods, first year mathematics, and two years of physics. The Diploma in Education and the mathematics subject are those which are available to all students at La Trobe, with the exception that students enrolled in the Graduate Diploma undertake each of these part time over two years. The physics subjects, Physics IE and IIE are new physics subjects at LaTrobe University which have been specifically developed for this diploma.

In the period leading up to the enrolments in both 1990 and 1991 there was considerable interest shown in the course: in 1991 nearly thirty applications were received. The small number of enrolments may reflect the financial burden and time commitment required for two years of full time study. There are, however, many reasons for continuing to offer the Diploma: reasons which impinge on issues of access to physics education, and reasons which have to do with the nature and quality of current physics education at secondary and tertiary level.

The traditional route to becoming a physics teacher in Victoria requires that students choose to study physics in years eleven and twelve of secondary school, and then do so again for at least two years at a tertiary level. Very few individuals who do not take physics at year eleven are able to gain entry to tertiary physics. The Graduate Diploma of Physics and Education offers a second chance to such people. The subjects Physics IE and IIE have been developed for students with no prior experience in physics and Physics IE assumes little mathematical facility: they offer a route into mainstream physics for students who wish to continue with their studies, and who are able to gain the necessary mathematics background. The course has been developed to be non-terminal. These subjects have been designed to take into account many of the current concerns about science education.

These trainee teachers come to their study of physics with a wide range of skills and interest; each student's perspective is informed by at least three years of study in a discipline which is not in the tradition of undergraduate physics. If we are able to teach them physics in a manner which allows them to maintain this perspective, their physics classrooms will provide us with some interesting teaching in the future.

UNDERLYING COURSE PHILOSOPHY

The challenge for Physics IE and IIE is to teach physics in a manner which:

- values and builds upon the skills and interests of each student,
- allows each student to understand the values and views of traditional physics while maintaining the perspective provided by his or her previous training,
- consciously identifies and reflects upon the processes of model building which physics exemplifies,
- critically evaluates the role which physics plays in our society and culture, and which reflects upon the influence of the past societal and cultural values on the creation of physics,
- encourages students to use mathematics as a language of physics, but also to communicate physics in a variety of other ways.

There has been over many years an accumulating body of work in support of the view that scientific knowledge is constructed rather than discovered. Writers such as Kuhn (1962), Whitehead (1925), and Woolgar (1988) have examined the processes of construction of scientific theories and shown that these are influenced by the social environment in which the scientists worked, and also by the "secret imaginative background which never emerges explicitly" (Whitehead, 1925, p.11); the shared beliefs about nature which influenced the investigations of these scientists. We support these views and thus chose to treat the body of knowledge and skills which constitute physics as essentially socially constructed, and to consciously examine the plurality of perspectives offered by this approach.

In developing this course we have been influenced by what may be called the Science, Technology and Society Movement, in particular the Science for Social Responsibility approach advocated by Cross and Price (Note 1, see also Cross, 1990), and those who advocate the teaching of the history and philosophy of science in the science classroom (Matthews, 1990; Arons, 1988, 1990).

We have also drawn upon the work of Driver (1983), Osborne and Freyberg (1985) and others in the area of what is known as "Alternative Frameworks"and that of the PEEL Project in metacognitive learning. For example, we often use Predict-Observe-Explain exercises (Gunstone, 1990) and concept mapping (Baird & Mitchell, 1986). Our students are encouraged to maintain a journal in which they reflect upon their learning. Our classroom activities also owe much to the materials produced by the McClintock Collective (Gianello, 1988), a group of science teachers based in Victoria who actively support the state's policy of equality of access to science education and redress of disadvantage for all students, with a particular focus on girls.

COURSE STRUCTURE

Physics IE is timetabled to occupy seven hours a week, in three blocks of two hours and a one hour tutorial. Each session involves a variety of activities selected from the following: teaching, discussion, problem solving, practical exercises, demonstrations, experimental work and comprehension exercises. The style resembles classroom teaching rather than tertiary lecturing. Practical work takes a variety of forms, and is performed when it best fits the topic under discussion, in contrast with the tertiary practice of running a separate laboratory course which may not bear much relationship to the lectures.

Physics IE is named "Multiperspective Physics". As its name implies, it provides a broad view of the origins, applications and processes of physics, approaching the study from a variety of perspectives. Some of these include: physics as a way of explaining; physics and its application to technology; physics and the personal construction of physical theory; and the people who have contributed to physics. Thus, for example, two-dimensional dynamics is taught in the context of the physics of traffic accident investigation; universal gravitation is taught via the historical sequence of ideas from ancient astronomy through to the determination of the shape of the earth; and introductory kinematics and dynamics is taught through an examination of the alternative frameworks which may be used to describe and explain motion, in particular the challenge to change perspective from Aristotelian to Newtonian.

The style and emphasis of the course are reflected in the assessment tasks. Two open book examinations, each of two and a half hours duration, are worth a total of 20% : the remaining 80% of the grade is made up of tasks such as short projects, case studies, essays, problem sheets and practical reports. Every student keeps a log-book of practical work and each is asked to maintain a journal.

Physics IIE is timetabled to occupy eight hours a week, and is taught in a similar manner to Physics IE. Its over arching theme is the process of theory construction in physics. This theme links, for example, the study of electromagnetism, quantum mechanics and nuclear physics, each of which offers a study of the role of observation and the influence of personal and societal values in the construction of physical theory. Other themes examined in Physics IIE are the interaction between physics and technology, and the impact of that technology on society. This approach proves useful in the study of electronics, and thermodynamics, as well as electromagnetism, quantum mechanics and nuclear physics. Rotational motion is taught through the application of a physical theory to explain the familiar phenomena of human movement. In the study of materials and structures, a series of formal models are constructed in order to provide an explanations for observed phenomena. This provides insight into the processes of modelling as they occur in physics, the variety of models available and the criteria by which such models are judged. Relativity and quantum mechanics provide the opportunity to assess the influence of mathematics on the formalism of physics.

Physics IIE is assessed via two open book examinations, each of two and a half hour duration, and each worth 10%; short projects, case studies, essays, problem sheets and practical reports, worth 60%; an extended experimental investigation worth 10% and a two thousand word essay on a reading project of the student's choice, worth 10% of the final grade.

The methods of assessment of Physics IE and IIE differ from those traditionally employed in tertiary physics. They are chosen to complement the chosen career of our students. It seemed to us essential that teachers of physics should be able to express their ideas clearly in words as well as symbols and in oral as well as written form. There is more concern here to develop in the students the ability to discover,to synthesize and to explain ideas, rather than recall facts. Hence the emphasis placed on continuous assessment involving a variety of tasks. We have, however, retained the examination as a means to provide the students with motivation to review work, collect data, summarize their notes and generally to think about the material taught in the preceding semester. An unfortunate consequence of the use of an examination is that it assumes a greater significance in the eyes of some students than its weighting warrants. Also it 'devalues' the other assessment tasks, and styles of learning that they are intended to encourage.

REVIEW OF PROGRESS

The Diploma's first intake of students occurred in February 1990. Eight students enrolled; three women and five men. Two of these withdrew during 1990, two others failed to satisfactorily complete Physics IE: four remain, three men and one woman. Seven students enrolled in the second intake, in February 1991; two men and five women. One woman has recently withdrawn from the course. The reasons given for withdrawal vary, but a common theme is that the students discover that they no longer wish to be teachers. Difficulty in sustaining effort in the face of an large workload is another.

The requirement that students complete one year of tertiary mathematics proved an insurmountable hurdle for at least three students in our initial intake. For this reason, we now require that applicants should have studied mathematics to at least year twelve level. Any level of year twelve mathematics is acceptable for entry to Physics 1E: a minimum requirement is the ability to perform simple algebraic manipulations. We are acutely aware that this restricts access to our course, but are constrained by the requirement to produce graduates who are able to teach physics at the senior levels of high school, and who must at least be able to cope with the mathematics this demands. Also, as one progresses in physics, the material is increasingly presented in the language of mathematics: whilst we would wish to challenge the status of mathematics as the only language of physics, it is certainly an important language, and a degree of fluency is essential.

The aspect of the Graduate Diploma in Physics and Education about which we have received overwhelmingly positive feedback from the students are the two physics subjects, Physics IE and IIE. This is not to say that there have not been suggestions for improvements: however, anecdotal evidence indicates the attempt to teach tertiary physics in "context" has resulted in an interesting and challenging course. Several students have remarked on the contrast with secondary physics; many say that it is easier to learn physics when they can recognize its relevance. There is no doubt that the improved maturity of the students is a major factor in this view; but we feel that the structure of Physics IE and IIE also contributes.

Interviews with students indicate that they perceive this course as being "easier" than mainstream physics, and that this is a factor influencing their decision to enrol. While we would agree that the course is different, we would challenge the description of easy. In some ways, our students seem to view a non-mathematical approach as an "easy option" and undervalue the skills of writing, data-gathering and critical analysis which we demand.

Our ability to challenge the students' view of physics ("real" physics) as being a mathematical exercise, deterministic and reductionist in the Newtonian tradition has to some extent been constrained by our perceptions of what is necessary in the preparation of secondary teachers. These perceptions are informed by our many years of experience teaching in secondary schools, by our involvement with curriculum development projects and by our acquaintance with the literature. They confirm to us that the successful teacher of physics in a secondary school must be able to use the techniques of Newtonian mechanics, to be familiar with and fluent in the use of its concepts. We would like to encourage our students to be aware also of the limitations of this style of thinking: it is interesting to note that most of them resist this fiercely.

When Physics IE and IIE have dealt with the applications of physics to a "real life" situation, or when we have used a model constructed in physics to explain a natural phenomenon, such as a rainbow or lightning, the students have displayed real interest. When we attempt a critical analysis of the structure of physics, drawing attention to the assumptions and uncertainties inherent in the processes of theory construction, we find that many of the students regard this as inappropriate material for a physics class.

The students demonstrate a need to regard physics as real and useful; only one of them was initially able to regard the process of theory construction as a type of mental adventure which has intrinsic value. An extreme case is the student who rejected quantum mechanics as being of no use. When questioned further it became apparent that he could see no application of its principles in his own life, on the macroscopic scale. A discussion of diodes and transistors modified his attitude slightly; the power of the theory and its impact on classical determinism left him unmoved.

These instances raise for us many questions regarding the views of physics commonly held by teachers in secondary schools, and therefore the views of physics presented to students. Our experience is that for a majority of our students their perception of appropriate learning is instrumental, and that for them a large factor in the value of physics is its power to explain and control natural phenomena.

It is encouraging, however, to note that with at least one individual there has been a shift in attitude as a result of this approach to teaching physics. In this case, a student who in July 1990 indicated strong agreement with the statement

> Physics is about the truth, there is not room for discussion like in humanities

had, by May 1991, changed his position.

> Physics is about the truth, no, I disagree with that...funny....no, they are really models...there are many descriptions for why this is so and either one can be true, I think and...

His explanation for why his view had changed is interesting:

> Mr. Maxwell had an impact.

This student could only have been referring to our study of the formal process of theory construction in electromagnetism, and the belief in simplicity and symmetry which influenced James Clerk Maxwell in the development of his equations.

It is easy to dismiss this shift in a single individual as insignificant, but we would attest that it is indicative of a change in the views of three of the four students currently in the second year of this course: they may not personally subscribe to the idea that physics is a socially constructed body of knowledge, but they are able to acknowledge that a plausible case may be made for this position. The fourth student is the one referred to earlier, who already held this view. Whether this change in attitude can survive the transition to a secondary school classroom remains to be determined.

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GENDER-INCLUSIVE TECHNOLOGY MATERIALS FOR THE PRIMARY SCHOOL: A CASE STUDY IN CURRICULUM DEVELOPMENT

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ABSTRACT

This paper describes how an idea for technology education materials developed into a process for producing unique curriculum modules for teaching technology in a gender-inclusive way to primary children. Using a case-study format, the paper describes the interaction between participants, the sequential evolution of the materials themselves and the degree to which success was achieved in terms of the original goals. The study demonstrates how an awareness of gender bias needs to be a feature from the earliest stages of curriculum development, through to the trialling and modification stages. The curriculum materials were a product of effective cooperation between teachers, science educators and community representatives. They utilise a "process" approach to the teaching of technology and in this presentation, we demonstrate how this same approach is a useful framework for describing this particular curriculum development.

INTRODUCTION

This paper describes the initiation and development of a primary curriculum project in technology education. The case study utilised action research methodology, compiling the authors' first-hand experiences and transcripts of meetings held throughout the project with advisers and development teams, and analyses of the successive drafts of the curriculum materials as they were developed. The value of the case study lies in its highlighting of particular ideas and issues which have relevance to technology education in general and technology education for girls in particular.

THE BEGINNING: DEFINING THE FRAMEWORK FOR CURRICULUM DEVELOPMENT

Identifying a need

Early in 1987, staff of the Western Australian Technology Directorate, perceived a need for technology education materials in Western Australian schools. They proposed to develop a programme of innovative school-based technology projects which foster practical technical skills, project management skills and creative problem-solving abilities amongst students and teachers. The focus was on technology as a process whereby students would gain a greater understanding of the product life cycle and an increasing awareness of the skills required to develop a project from an idea to a viable product or process. From the start, the need to address gender bias was recognised in one of the proposal objectives: to reduce the stereotypical view of technical/technological skills as distinctly masculine in nature.

The process of this curriculum development forms an interesting juxtaposition with the actual curriculum products themselves, in that it shares the major steps of a technological design process, which in turn came to provide the structural framework for the curriculum materials. The design process in Fig. 1 has been used as a framework for describing the development of the curriculum materials. Note the similarity with the technology design process in Fig. 2 which formed the basis for the teaching strategies contained in the materials.

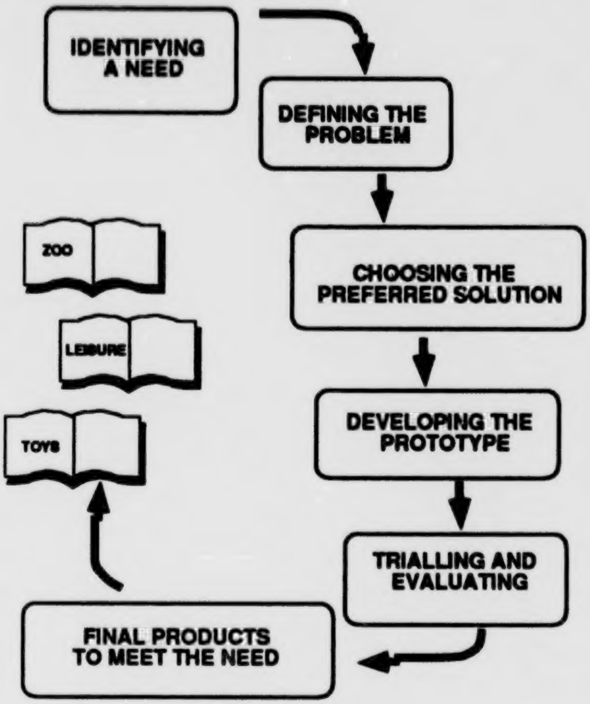
IDENTIFYING A NEED
DEFINING THE PROBLEM
CHOOSING THE PREFERRED SOLUTION
DEVELOPING THE PROTOTYPE
TRIALLING AND EVALUATING
FINAL PRODUCTS TO MEET THE NEED
ZOO
LEISURE
TOYS

FIGURE 1. CURRICULUM DEVELOPMENT AS A DESIGN PROCESS

The idea received support from canvassed teachers and teacher-educators and a Schools-based Advisory Panel was established to formulate a programme for the development of technology education materials for schools. Representation on the panel included people from public and private sectors, science educators from tertiary organisations and teachers.

Defining the problem

Over the next two months a proposal was formulated for submission to the state government's Technology and Industry Development Association (TIDA) for funding. The proposal's components were:

- development of an upper primary modular curriculum resource to the prototype stage. The modules were to have a common philosophical framework.
- for each module, a team of classroom teachers would work interactively with a consultant adviser from a tertiary institution.
- the current Advisory Panel would oversee the development of the modules.

The focus on primary school was justified on the basis that there was sufficient scope in the existing curriculum and timetable structure for teachers to incorporate technology and that it would be easier to achieve participation by girls. Also, there were already initiatives in this area at the secondary level.

Choosing the preferred solution

Much time was spent by the Advisory Panel on the definitions and framework which might guide such a development. In the absence of a consensus view of a definition of technology, a set of working principles was defined:

- each project should attempt to solve a human need either identified by or relevant to the students.
- the projects should have no "right" or "wrong" answers -- the teacher to be used as a resource person rather than the supplier of a "blueprint".
- each project should include gathering additional information about the human problem to be solved and the principles relevant to its solution from the community as well as the school.
- each project should be "hands-on" involving the students in assembling the required information, materials and expertise and then using them to create a product -- a working model.
- the children should assess the degree to which the project achieved an acceptable solution and suggest improvements, and teachers should provide an atmosphere in which students do not equate failure to achieve objectives with failure in the unit.
- all materials provided and their presentation should encourage full participation of girls and children from minority groups. The use of any materials or terminology that present prejudicial images must be avoided at all costs.

Unique aspects of the prototype modules which were essential to their development were the emphasis on guiding the children to identify a definite human need to initiate the sequence, the identification of procedures for product evaluation by the children themselves, as a concluding activity, and gender inclusiveness.

Three project teams were formed (each comprising 2 - 3 selected classroom teachers and an adviser) and provided with the Panel's working framework. The Advisory Panel's role now shifted from development/initiation to a monitoring role, overseeing the project teams over the next six months as they developed the curriculum prototypes.

THE DEVELOPMENT OF THE PROTOTYPES

Topic selection and the process framework

The teachers had little experience with technology as a curriculum area and, while each team worked separately on their respective modules, group discussions held through the development period were valuable education sessions where topics areas were brainstormed, ideas were shared, definitions clarified, and common approaches identified and developed. Previously-developed curriculum materials such as the New Jersey project (Fricke, 1987) provided some educational guidance. Panel advisers stressed the importance of encouraging children to frame problems in technological rather than in scientific terms, thus ensuring a technology focus. The need to highlight group work and to ensure girls' participation was re-emphasised.

Within a short time, the teams had chosen three project topics, Zoo Technology, Leisure and Advertising. It was agreed that each module would provide an example "product cycle" which teachers and children could complete, followed by open-ended activities for further development.

Project briefs were presented to the Advisory Panel for approval. At this stage they were rough outlines, testing the scope of the topics to provide design and construction activities and outcomes. The Zoo brief used a design process to most advantage to "...design a new look zoo which provides greater freedom, as well as a healthier, natural and aesthetically pleasing environment." Here the interesting points were the innovative idea of "zoo technology" as a theme and the use of a "scenario" approach to defining the problem. Children were asked to play the role of the Zoo Director who was given unlimited funds to develop a "new look" enclosure for a chosen animal.

The Leisure brief acknowledged the inclusion of a design process but as yet had no specific focus. It provided "brainstorming" pictures of two leisure products as a prelude to designing new goods to fulfil needs via a design process.

The third project team had a "mis-start" in that the problem was to "...use technology to plan and develop a method for promoting and selling a product." Interestingly, their definition of technology at this early stage reflected this marketing focus rather than a product development focus. On discussion with other project teams they quickly realised that their project centred on the use of technology to develop any product rather than the design and construction of products or processes which incorporated technology within them. They saw their product as a "Media" rather than a technological product and reorientated their definition of technology towards "problem-solving by design and construction" using the themes of toys and sport. They drew heavily on the concept of "artefact" and with the cricket ball as an example, used "artefact analysis" as a prelude to the actual design process.This was followed by a set of potential problems based on toy creation.

From these first "briefs", the overall project schemata were emerging:

- all utilised a process approach -- reflecting the Advisory Panel's view that it dovetail with any potential secondary level unit ;
- all began the process with some kind of problem to be solved;
- data-gathering (research) and design were integral parts;

- all emphasised a testing and evaluation stage of the product;
- examples of "products" or "technological artefacts" were "brainstormed to orientate children towards the design process: e.g., the functional characteristics of cricket balls, runners or bicycles, zoo enclosures.

The "Getting started" controversy

At this juncture, a controversy developed which occupied considerable discussion time with teachers and advisers. It centred around the definition of the problem(s) for children to investigate. Would children define their own problems? Could they define their own problems? What should/could be the teacher's input? How prescriptive should that input be? How can the relationship between a need for change and the definition of a problem to meet that need be developed? All the teachers had recognised an important element that separates technology as a process from other problem-solving algorithms (e.g. as in science) - entry to the design process implied that a need for change had been demonstrated and that a technological problem statement to address that need could be defined.

While some advisory panel members wished the materials to remain as open-ended and non-prescriptive as possible, there was a strong feeling among some of the teachers that the idea of the technology design process would overwhelm many teachers, that teachers would need some kind of prescriptive framework to encourage them to make a start. There was disagreement as to whether children and primary teachers who lack confidence could go straight into the design process, defining their own problems. Was it necessary, for example, to generate some feeling of "dissatisfaction" with current products or processes as a stimulus for brainstorming new ideas? If so, did teaching strategies need to be included in the teachers notes? Was there a need for some kind of "springboard activities" for inexperienced teachers and children to get into the design process itself?

The teachers' concerns won the day and background activities were developed, leading children to the identification of the problem and hence entry into the design process. These starter activities were to become a significant and unique feature of the materials. In the early versions of the Zoo module they were given a separate section -- "Getting Started" and in the final versions, this model was adopted by the editors for all three modules.

The prototypes - filling out the framework

As more sophisticated drafts were produced over the ensuing months, more structured frameworks and more specific topics emerged. In all three modules, the idea of having an introductory sequence of activities which helped children "Identify a need" was developed and this in turn led to the generation of a "Statement of Intent" which led the children directly into the "Design Process". Teachers' notes were detailed, providing strategies for each lesson or step in the design process. Each provided sets of open-ended design problems within the topic for additional follow-up. As well, introductory aims and objectives, suggestions for subject integration and suggested resources were components in all three modules.

It is interesting to compare the methods which each team used to introduce children to the design process via the writing of a "statement of intent", considering the lengthy discussion over this issue. Each team approached it slightly differently and with differing degrees of specificity.The Toys and Leisure modules took advantage of historical approaches (one to dolls, the other to bicycles) to introduce the concept of product change for improvement. (The "Toys" team had abandoned their original cricket-ball approach when, in initial trialling, it proved too difficult for both teachers and children to analyse and was deemed by the advisers to be too male orientated).With regard to the framing of a technological problem, the Leisure module was the most specific - it simply provided one : "For the purpose of this project the area has been decided for the group. The following design process requires the children to make something that can be attached to a bicycle so that the rider can signal the intention to turn left or right." At the other extreme was the Toys module. While it suggested an introductory starting activity so the children could experience design and construction ("Building a toy which uses drinking straws, suitable for a five year old"), it then provided a varied list of open-ended problems from which children could choose to problem solve.

The Zoo module concentrated on product evaluation of current zoo enclosures. It then used a scenario approach to encourage children to create their own, individually tailored statements of intent: "If you were the Director of Perth Zoo with plenty of money to spend and you wished to implement a major project immediately, which enclosure would you improve?"

THE TRIAL OF THE CURRICULA

Volunteer teachers from 5 primary classrooms (years 4 - 7) tried out the three projects over a class term. A detailed description of the trial and its outcomes, particularly with regard to gender issues, has been presented elsewhere (Kinnear, Treagust, Rennie & Lewis, 1989; Rennie, Treagust & Kinnear, 1992) and a summary is presented here. Data collection methods included questionnaires to children and teachers, classroom observations and teacher interviews.

Teachers used the resources materials with few problems and readily translated the process approach to technology in the classrooms. There were several general outcomes:

* Children of this age group, if allowed, tended to skip over the research and alternative solutions phases of design, moving with impatience into the design and construction phases on a "one solution" basis. This in itself could be a learning process as when designs failed to work a rethink was required.

* For some classes, some activities were more difficult to do than others, whether because children were unfamiliar with some strategies (e.g., group discussion/evaluation of toys), materials were difficult to come by (e.g., bicycle parts), or the problem was creatively difficult for children of this age level (e.g., toy with straws). For these reasons, it was important to provide flexibility of choice for teachers or children.

* The project materials stimulated girls' interest in technology and they responded as enthusiastically as boys to the activities. They responded particularly well to the group work strategy used throughout. (Girls who normally tended to take passive roles in whole-class situations took active roles

in smaller groups.)' In the single-sex classes, girls enthusiasm was very high, with much out-of-class work. This was true whether the specific topic was wet-weather clothing (a more traditional female subject) or the design and construction of signalling devices (perhaps non-traditional).

However, gender differences were apparent during the use of the projects:

- there was a tendency for boys to construct toys of interacting parts, whereas girls often tended to make passive board games and chose "passive" toys for discussion and analysis;
- boys worked less well in group situations, with more teacher attention required to encourage them to work effectively and cooperatively;
- a knowledge of tool-use benefitted the boys. They tended to use more tools and use them more readily;
- the degree to which current technologies were used in sketches reflected differing experiences which could be gender-based. e.g., boys were better able to produce realistic designs of futuristic cars which showed a knowledge of current features;
- teachers themselves could have gender-related views as to what was a suitable technological activity, e.g., one male teacher considered the "clothes" activity unrealistic as a technology activity and suggested more realistic ones such as "racing bike designs". On the other hand a female teacher had used the clothes activity with much creative success.

All the children had positive initial perceptions about technology and these perceptions were maintained or increased during the topics. However, in one class, boys perceptions of girls' capabilities in technology became significantly more negative after experiencing the topic. This was a classroom where some girls had shown some reluctance initially to participate in the topic and they had shown inexperience with handling tools such as the video camera.

The final product

In the light of the classroom trialling, some alterations were made prior to the final editions. The importance of gender inclusiveness was explicitly stated and teachers were reminded of areas where gender bias can occur and strategies were suggested to ensure equal participation in the classroom activities.

The success of the activities introducing the design process for product development encouraged the editors to formalise these as "Getting Started" activities in all three projects and show their relationship both strategically and philosophically to the design process. Thus while the three projects maintained a degree of individuality with regard to page-by-page layout, they now all reflected three stages of presenting technology to children (figure 2):

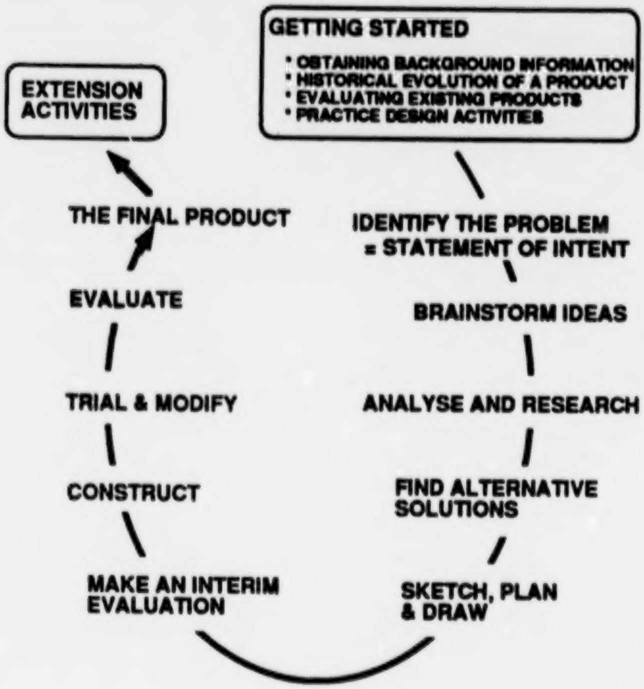
GETTING STARTED
* OBTAINING BACKGROUND INFORMATION
* HISTORICAL EVOLUTION OF A PRODUCT
* EVALUATING EXISTING PRODUCTS
* PRACTICE DESIGN ACTIVITIES
EXTENSION ACTIVITIES
THE FINAL PRODUCT
IDENTIFY THE PROBLEM = STATEMENT OF INTENT
EVALUATE
BRAINSTORM IDEAS
TRIAL & MODIFY
ANALYSE AND RESEARCH
CONSTRUCT
FIND ALTERNATIVE SOLUTIONS
MAKE AN INTERIM EVALUATION
SKETCH, PLAN & DRAW

FIGURE 2. A DESIGN PROCESS FOR TECHNOLOGY WITHIN THE COMPLETE MODULE

- A "Getting Started" stage where the children were encouraged to think about technology as meeting needs, to consider current products and potential design improvements to meet specific needs, and out of this to develop a 'Statement of Intent" -- the framing of a technological problem to confront that need.

- The "Design Process", a sequence of clearly-defined steps (each with detailed teaching strategies) whereby the children designed, constructed and evaluated a product to meet the defined need

- Extension activities -- open -ended problems within the theme which provided additional design possibilities.

MEETING THE NEED

The formal structure of an advisory panel plus development teams proved effective for module development. The involvement of representatives from public and private agencies provided valuable workplace input. The interaction of teacher-educators and classroom teachers was essential for the development of an appropriate framework which was both philosophically sound and developmentally and practically appropriate to the primary setting. The involvement of a third teacher educator as additional research assistant in the evaluation process provided a measure of independence and objectivity in the trialling process.

Gender inclusiveness

The concept of gender-inclusiveness, that the teaching materials should be attractive and effective for both boys and girls was incorporated into the project from the start. It was one of the aims of the project as initially framed by government representatives, it became one of the advisory panel's guiding principles' for the curriculum development, and it was a prominent focus of the trialling and evaluation procedures.

Gender inclusiveness is reflected in the topics chosen as themes for design. Animal welfare (Zoo), bicycle safety (Leisure) and dolls and toys for young or disabled children (Toys) are topics which appeal to the experiences and interests of girls in particular. At the same time, they in no way detract from the interest of boys, as the trialling demonstrated. Similarly, gender inclusiveness is reflected in the focus on group work throughout the materials, whether for evaluation and discussion of products, or for design and construction of improved products. While this enhances girls' participation, it provides an opportunity, as one teacher put it, for teaching the boys to "...socialise and learn to listen and think about what others have to say". Lastly, gender inclusiveness is reflected in the involvement of girls in tinkering activities within themes they can relate to, and where needed it explicitly addresses situations where, despite the best of intentions, girls may still be disadvantaged in technology classrooms. In summary, the modules proved extremely effective as vehicles for generating enthusiasm and interest in technology, not only in girls, but in boys as well.

Technology as a process of meeting needs

One of the aspects which sets technology apart from other disciplines which incorporate problem-solving such as science is that it is problem-solving to meet human needs. The defining of such a problem is the initiator of the technology design process which was used as the framework for the modules.

The controversy over whether structured pre-design strategies were required either to ensure children could identify a suitable problem, or to see the relevance of a given problem led to what we have termed the "Getting Started " activities. These ensured that the design process was always set within the "need" context. This contextual element to be most important in technology education (Williams, 1991). Technology, as a process for producing goods and services, is becoming increasingly subject to evaluation and criticism. The rise of the concept of sustainable development, the shortcomings of an approach which measures "need" only by an economic yardstick and which fails to account for social and environmental costs and consequences has contributed to the widening critique (Willoughby, 1990 provides an excellent summary). By presenting technological problems to children always within the context of human need, the three modules provide an opportunity for children and teachers to question and evaluate the reasons for the technological development and, if appropriate, its potential environmental impact. In the curriculum framework presented here, the Getting Starting activities provide an appropriate point for teachers and children to evaluate and discuss the social and environmental context of the technologies, current and planned. This ability to evaluate need and potential consequences as a part of framing the problem definition, and prior to the design and construction activities are an important aspect of technology education.

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KEEPING UP: A DILEMMA FOR SCIENCE TEACHERS.

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Monash University.

ABSTRACT

This paper is based on interviews with seventy-five science teachers in twelve schools across Australia. The interviews were conducted as part of a D.E.E.T. Project of National Significance. The purpose of the project was to develop a strategy for the professional development of science teachers. The main purpose of our interviews was to listen to teachers' views on what such a strategy should try to achieve. We asked them to talk about conditions affecting the quality of their work, their attitudes to teaching, their professional development, their careers, the evaluation of teaching, and Award Restructuring. Through these interviews we came to understand how many science teachers are loosely connected with potentially valuable sources of support for their professional development. In this paper we focus on one group of "loose connections"; those between science teachers and scientists in other fields, research in science education, and their colleagues within science departments in schools.

INTRODUCTION

This paper is based on an interview study with seventy five science teachers as part of the Science Education Professional Development (SEPD) Project. The Project was commissioned by the Commonwealth Department of Employment, Education and Training as part of its Projects of National Significance Program. The brief was to develop a national strategy for enhancing the professional development of science teachers.

When we started the interviews late in 1990 we were aware that there was disquiet about the "condition of teaching". Australia was starting to share the concerns about the future of teaching as an occupation that had given the Americans such a scare in the early 1980s (National Commission of Excellence in Education, 1983; Carnegie Forum on Education and the Economy, 1986), and which had led the OECD to initiate its activity on The Condition of Teaching (OECD, 1989). In Australia there was increasing concern about the decreasing proportion of the ablest graduates from secondary schools who were being attracted into science faculties in universities and science education courses in CAEs. Any national strategy for the professional development of science teachers that did not address these issues about the conditions of teaching risked being irrelevant.

In developing a strategy for professional development, it was obviously important to talk to science teachers to ascertain their views on the quality of what they had experienced, what they wanted in the future, and what they thought the Federal Minister for Education needed to know if the country was to become "cleverer" or more "intelligent". But our interests went further. We wanted to understand, from the science teacher's point of view, the context within which they worked and the factors that helped or hindered them doing their jobs as well as they would wish.

It is obvious that if we want to do something about the quality of science teaching then we must understand first what shapes teachers' attitudes to their work and the "quality of worklife" as they perceive it (Louis & Smith, 1991). There is not much point to organising quality in-service education programs if teaching is becoming less and less attractive to able graduates as a career. This also applies to experienced teachers who are leaving teaching, or losing heart, because they do not feel that the returns in terms of status and conditions are in balance with their personal investment in the job.

In this paper we report on some of the data which reflects the isolation of teachers from a range of influences on their professional development and the quality of their work. These science teachers have little opportunity to "keep up" with developments in science research and education and their workplace is not organised in a way that encourages or expects them to.

METHOD

We conducted an initial "wave" of interviews late in 1990 with thirty teachers in six schools in five of the eight states and territories in Australia. The topics we explored with teachers included their attitudes to: work, students, their sense of status and career, workplace, department, views on what helped or hindered them doing their jobs as well as they would wish, professional development, approach to teaching science, the evaluation of teaching, and the impact of recent system-level policy.

These semi-structured interviews aimed to understand contextual influences on teachers' work through the eyes of science teachers themselves. They were intended to be exploratory and hypothesis-generating. In-depth interviews were the most appropriate method because our purpose was to try to represent the way science teachers viewed their work. The second wave of interviews in seven more schools focussed on developing and testing out the significance of the issues and themes which emerged during the first wave.

There is no such thing as a representative sample of schools, especially in a study of this size, but we did ask system people in the first wave to suggest schools that were "ordinary run-of-the-mill" schools. All were government schools. In the second wave we included one Catholic systemic school, and one independent school noted for its innovatory programs in staff development and evaluation, to improve the process of interpretation and hypothesis-generation.

MAJOR THEME

One of the main themes which emerged from the interviews was what we came to call "loose connections". Through this interpretation we argued that many science teachers have a weak professional identity in the sense that they are loosely connected with: other teachers, in-service education, scientists and wider science activities generally, feedback about their performance, their professional associations, professional standards, sense of career and respect from administrators, parents and the community.

The loose connections are in two related domains. One is associated with the lack of recognisable or demonstrable reference points and the other with professional standards in science teaching. These represent weak organisational controls over teachers' work. This has its "up side" - a sense of autonomy. But it is a false sense of autonomy. The "down side" is that science teachers as a group exercise little power over a range of "professional" issues that have the potential to provide them with greater status and a stronger skill-related concept of career development.'

The organisation of schools appears to reinforce this view. Administrative functions appear to take precedence over classroom teaching. Developing a career as a science teacher, doing the job better and maintaining a focus on learning as the prime function of teaching is at odds with existing career expectations.

> Good teachers get shuffled into administration and we haven't got good teachers who continue to be good teachers.

Focussing on teaching and learning as the important function of schooling should help to redress this imbalance. To do this, teachers' professional knowledge needs to be valued. Fostering the links that could enhance science teachers pedagogical content knowledge needs to occur. One cannot occur without the other. Without the links, the professional knowledge may well be limited, without valuing the knowledge the links will remain weak. Keeping up is a dilemma for science teachers.

LINKS WITH SCIENCE

Scientists? A sense of identity is important for all of us - personally, and in terms of our work. For teachers, personal and professional identities are closely intertwined. We were interested in the extent to which science teachers identified themselves as scientists, how frequently they interacted with scientists from other fields such as universities and industry, and the methods they used for keeping up with their field. These questions seemed to have important implications for a professional development strategy. How strong were the links between science teachers and the wider world of scientific activity?

Most of the science teachers we talked with had a Bachelor of Science and a Diploma in Education, or a Bachelor of Education from a college which included units of science. Most had moved directly from tertiary education into teaching. But there were several with other backgrounds - Engineers, Micro-biologists, Chemists, a Geneticist, a Metallurgist and a Surveyor.

Is teaching science doing science? We asked teachers if they thought of themselves as scientists. Although their individual definitions of a scientist varied, only one in four regarded themselves as a scientist. Fewer college-trained teachers were likely to think of themselves as scientists. Even honours graduates often said that they hardly ever used anything they learned in their degrees in their science teaching. There is a major issue of concern here in the current preparation of science teachers which needs to be addressed. It would appear that undergraduate education in science itself rarely gives students the experience of "feeling like a scientist". Being qualified to teach science, discussing scientific ideas with students, and performing scientific tasks with them such as observation, hypothesizing and experimentation, did not seem to be sufficient to allow science teachers to regard themselves as scientists.

Those who felt they were scientists still saw a distinction between doing science and teaching science. "Doing" science involved scientific research; "teaching" science was passing on scientific information and skills. An important criterion in this regard was the need to be conducting scientific research.

> ...the kids see me as a scientist, but I'm not. As a scientist I would do my own kind of research and I'm not. I'm using others' research.

> I used to think of myself as a scientist while I was at University, but I didn't when I started teaching which is a bit sad I suppose.
>
> I'm not doing the work that I would associate with a scientist...investigative type work.

One teacher exclaimed "I just wish that I could just feel like a scientist once in a while." He meant work in a university, not a school.

For these teachers, being a scientist appears to mean being involved in specialised scientific research, performing experiments and adding to the knowledge base of science. They do not see the activity of teaching science as doing science. We do not have the space here, or the evidence, to explore more fully the implications for practice of this disposition, but it seems to us that they would be profound. We suspect, for example,that the development of a constructivist perspective, of seeing learning from the point of view of the learner, only comes with the appreciation that the activity of teaching science is essentially doing science.

There are interesting questions here which could be followed up in later studies. We wonder if teachers in other subject areas make such a clear distinction between teaching their subject and participating in it as an intellectual activity. Would an English or philosophy teacher think they were not doing English or philosophy as they taught and discussed a novel, or a point of logic? Maybe this is the distinction we risk falling into when we teach outside our field of expertise, and, have to rely heavily on textbooks. It is the same distinction that people like Stenhouse and Eisner argued so strongly against back in the 1960s when they rejected the concept of psychologically defined behavioural objectives. Much the same point is made by Lampert (1988) on teaching mathematics with "integrity, honesty and courage", and Prawat (1991) when he talks about the "value of ideas" and argues that subjects or disciplines are intellectual activities or ends in themselves, not merely means to teaching some abstract notion of "thinking skills" or problem solving ability.

The view that teaching science is different from doing science was especially true for teachers with college training who felt that they did not have a subject background equivalent to a major in a university degree. Most of our interviewees felt separated from their field of expertise because they no longer did science. It appears that part of the experience of teaching science often means teaching outside one's main area of subject expertise. Biology specialists, for example, often have to teach some physics and chemistry in years 7-10, and vice versa for physics and chemistry teachers.

Contact with Scientists Outside School We asked teachers how often they met with scientists who worked in other areas such as industry or university. Teachers found this question a little odd at first, as if surprised that anyone thought they should. Though all expressed a need to update their science knowledge, only two teachers stated that they had any regular contact with scientists. And for one of these it was a result of his regular "scrounging" around the university labs to get out of date, but still functional, equipment for his school. Another asked "Does meeting the people at the Zoo count?". The lack of contact with wider scientific activity was recognised by teachers as a problem.

> ....to maintain your own professional knowledge, content knowledge is one thing that I think is lacking. If we are going to talk about science

> and technology and communicate effectively with kids about recent developments it's hard working from a text book that is five years out of date....
> ....I see that it would be good if we could meet scientists and see how they work...the connection between science research and science teaching would seem to be important...I think there's a big gap.
>
> How many days would you have met with scientists? Never, unless you were going to include a day when we went to the Tech with the school kids as an excursion, which is not really the same thing.
>
> I can't ever remember talking to anyone...I think 3 or 4 years ago I visited the laboratories...I knew someone who was there and they were having an open day...she knew I was interested. I thought that was fascinating and I wished I could take my chemistry class because I thought it would stimulate them.
>
> Well, I was thinking in fact of my brother...he was a meteorologist he would be the main one...I wouldn't have spoken to anyone outside of that.

The difficulty for many of these teachers was that they had lost contact with scientists when they moved into teaching. Even those who had worked as scientists lost contact with their colleagues and their field of expertise.

Keeping up with "science" We asked teachers to talk about the methods they used for keeping up in their field. The most common avenue for keeping up with "science" was to watch the television programs Quantum, and Towards 2000. Few had the time or inclination to read journals. In most schools, few journals were available. The most commonly mentioned journal was The National Geographic. Science teachers struggle to relate to the discipline in which they were trained, find it difficult to keep up to date with recent trends in science, and have limited contact with researchers in their field.

This feeling of slipping behind and being increasingly out of touch is another example of how the subject one teaches is itself an important factor shaping the context within which a teacher works, as Stodolsky (1988) and others have found. It seems that for science teachers - perhaps more so than for teachers in other subjects - there is a unique pressure or expectation to keep up, to stay in touch. In practice, of course, there is little time or opportunity to keep up with their area of specialisation in any organised way. Nor are there specific career rewards for those who gain further qualifications in their own time. The anxiety of slipping behind is combined, as we have seen above, with feelings of inadequacy in subject areas in which they have not specialised, but are still compelled to teach.

Scientific isolation was a concern for many. Talking to colleagues was often cited as the method used to keep up with advances in science, but this source of new information was limited to informal, often accidental contacts. It seems that the majority of these science teachers work in a context where there are weak connections with scientists and the wider scientific community and where they do not have confidence in their identity as scientists. This finding would seem to be a source of some concern and to have important implications for professional development policy, but it would be true to say that most teachers saw it as just the way things were. They were resigned to it and there was little "clamour" out there for something to be done about it.

RESEARCH IN SCIENCE EDUCATION

We asked teachers to talk about their approach to teaching science and the most significant changes they felt they had made in their methods during their careers. We were interested to know about the terms in which teachers articulated their teaching methods, whether they felt a sense of on-going professional development, and what had been the most important avenues for their professional development. From their responses we hoped to be able to gauge the salience of research in science education in their professional work.

Few teachers were able to discuss the impact of research in science education on their teaching. One of the most common terms teachers used to describe their approach was "hands on". This appeared, on further probing, to be a cover-all term that included a wide range of activities except direct, chalk-and-talk teaching.

> The way the teaching in our General Science is going it's really quite different. We're trying to open it up and make it a lot less content based. Because of that change we are shifting the emphasis from learning [memory], to [learning for] understanding.
>
> ...slowly gotten into more group work and moving away from the teacher being the centre of attention - getting the kids to do a lot of it.
>
> more people-centred too. I get them to do a lot more activities than I ever did before. They don't copy nearly as many notes.
>
> Nowadays we tend to me more subtle in our delivery of our material. We try to make it much more interesting, much more inviting to the students, much more appealing.

Science teachers were making changes in their pedagogy to enhance students' desire to learn rather than expecting them to digest information. However, the reasons for this had little to do with developments in educational research but more in trying to better manage their students. It did not appear as though the transition to 'hands on' activities was particularly linked to better learning strategies in response to research findings. It was more because the link between intrinsic motivation for learning, student management, interest and enjoyment had been realised.

The need for better links between research in science education and classroom science teaching was often acknowledged, but first hand experience of this happening was rarely evident.Teachers indicated that informal contact with colleagues was, by force of circumstances, one of the main ways of keeping up to date with changes in the field of both science and science education.

The majority of science teachers believed that such updating only really occurred 'on the job' and that teachers were the best purveyors of such information. It appears that teachers once again make a virtue out of a necessity, as there are few opportunities to do otherwise.

> In my opinion, the teaching approach is something that is developed between the person and the class...that was the one thing about my development. Most of the useful strategies were developed in the school with teachers who had been there 20 or 30 years and knew what they were doing.
>
> ...over several years, people suggest things. You've seen materials, you choose bits from it, you adapt material. People give you ideas - try doing this, try doing that - and you slot them in, you drop out other things that haven't been working. It's more of an evolution thing.
>
> How do I learn new teaching skills? (Mmmm). The school of hard knocks. It's all trial and error. There was some guidance in the beginning.

Science teachers are loosely connected to research in science education. There appears to be no tradition of turning to it for learning or advice. Teachers never mentioned it as a source of professional standards of practice. It is little wonder that teachers struggle to define what a career in science teaching means. There is no well established professional consensus on what science teachers are expected to get better at in terms of their practice. They are not encouraged to further their own learning. The fields that are relevant to their learning are not linked to their development and the direct impact of such fields on the science teacher's work is seemingly limited. There are few connections between research in science, research in science education and the teachers of science. The practitioner in the classroom is adrift from the two disciplines - science and education - rather than being at the confluence.

> The older I get, the further my relevance will get away, and that worries me, and I feel that I really don't keep up.
>
> ...I have sort of scanned through articles and things like that, and I don't think I would be up with modern thinking about how kids learn science.

Science teachers need to be able to identify with the two disciplines that their work is linked to. A real sense of identity or professional community is important in delineating professional norms and standards, hence roles. It seems peculiar that Australia is expected to develop into a "Clever Country" yet the likely translators of such goals are poorly recognised and unrewarded for their involvement.

Science teachers, while not necessarily being able to be at the forefront of developments in science and research in science education personally, should at least be given the opportunity to reflect on these developments and to be actively involved in the process of putting theory into practice. More formal links and better communication between these fields could help to connect theory and practice in a more pragmatic way.

THE SCIENCE DEPARTMENT

We asked teachers to talk about their workplace, their interaction with colleagues, their heads of department, and their departmental meetings. We were interested in the extent to which their work was organised in order to provide opportunities for teachers to share and learn. Teachers frequently state that they learn most from other teachers. One would expect, as a consequence, that communication in the workplace would be quite good and that the workplace would be organised to capitalise on this fact. Science department meetings, for example, could be a regular opportunity for formalising the sharing of ideas and introducing colleagues to new teaching strategies and content.

Although teachers said they did share ideas and discuss their teaching, this was mainly at an informal level. Science department meetings were more likely to involve the day to day running of the department and its resources, passing on administrative data, but rarely discussing teaching per se.

> They are organisational...But, sitting as we do, we have quite a bit of interchange...quite often you'll be doing something and someone will look over your shoulder and say "What's that?" "Well, this is my idea for so-and-so"...It all depends on colleagues. We would actually sit down and talk about what we were doing and how we were doing it, and we actually know what each other's doing. It's a personality thing - some people work well together and some people don't.
>
> There are not many opportunities to learn, and when you have got free time, you often want to get your lesson prep. and your marking done, and you don't necessarily think about rushing to somebody else's class to actually have a look.
>
> Sharing ideas of teaching science, does that tend to get done in the department? I think informally I think when you have a formal situation it is usually to get across the business of the time. If I want to ask them how to do something, I won't come down to the meeting, I'll sort of chat to them at recess or I'll come down at a time when we're both free and I'll sort of say how is the best way to go about this? So I suppose that's updating my teaching techniques by asking them how is the best way to go about it?
>
> If the Science Mistress said do some lessons for the other staff, or could someone give their favourite lesson, or whatever, I'd say that was a great idea, come along.
>
> ...in my last school it was more of an influence there. You had a much bigger science department, and we spent a lot more time in each other's company. A bigger office that all the science staff were in. This one is very different...I have my own office. I'm not really communicating a lot with the other teachers, which is good because I get a lot of work done, but it's bad because I don't know what's going on.

There is little in these quotations that is new. We know that the opportunities for teachers to learn from and share with colleagues are usually accidental and informal and rarely organised or planned for. At the same time, we also know that teachers claim that one of the most important avenues for their professional development is shared work with colleagues and that other teachers are the most credible source of helpful ideas. Despite knowing this, little movement toward acting on this takes place in the way in-service education is designed, whether the in-service is within or external to the school.

One young teacher in her second year of teaching had never observed another teacher teaching in her school and no one had ever come to see one of her lessons. The culture of teaching amongst most of the teachers we talked with is still basically one of privacy and territory, and it appears unlikely that this would change even if teachers had more time. There appear to be few organisational controls or motivations to change to collective responsibility for the quality of work. Teachers are loosely connected even with colleagues in their own workplace.

The science co-ordinator's role varies from State to State in both status and function. Fostering the professional development of science teachers should be an important aspect of the role. To facilitate this function, science co-ordinators also need direction and help. One of the main components of the SEPD project is to develop a handbook of ideas that heads to science departments might use to develop a 'culture' of professional development in the workplace. Although many actively pursue avenues for professional development of their staff, it is not uncommon to find that the science co-ordinator is frustrated by the lack of time, information, system support and experience to be satisfied with their efforts. This adds to the science teacher's dilemma as the science co-ordinator may also be at a distance from researchers in science and education.

WHAT ARE THE IMPLICATIONS OF THESE INTERVIEWS FOR A PROFESSIONAL DEVELOPMENT STRATEGY?

It is clear from the interviews that there is disparity between the opportunity to keep up to date and the need to keep up to date with developments in science and research in science education. The gap makes science teachers cynical about the rhetoric of a "clever country". They see themselves as key players in realising such a vision, but as yet uninvited, certainly not enticed, to join the game.

We now know a great deal about how to provide effective further training and development for practising teachers. Shortage of knowledge in that area is not a problem. Shortage of investment certainly is, but no strategy for professional development stands much chance of widespread success without parallel improvements in:

- our structures for giving recognition in career terms for demonstrable improvements in practice, which in turn is dependent on;
- the validity of our methods for the evaluation of teaching, which in turn are dependent on,
- the soundness of the knowledge base about quality teaching and learning we use when evaluating teachers for promotion.

We need to move on these three fronts to develop a credible career structure for recognising and rewarding advanced levels of expertise in teaching if our professional development efforts are to seriously engage the majority of teachers. The only avenue currently available to give support to a move in this direction is Award Restructuring

It seems to us that a strategy for enhancing the professional development of science teachers needs to strengthen the sense of collective responsibility of teacher organisations by:

1. Strengthening the motivation and the reward system for professional development in science education. We believe that the current system for recognising, and giving reward for professional development in teaching, as demonstrated through high standards of professional practice, is very weak compared with many other professions.

2. Clarifying and strengthening the concept of career development in teaching and making clear how it differs from merit pay or career ladder schemes is a second component . This is a critical distinction, but it is proving very difficult for many to apprehend. Probably because we are so used to equating career advancement with job promotion whereby each advancement entails different responsibilities and a change in job description. More appropriate models for teaching are professional career structures, such as those for academics, where hierarchies operate without strict demarcation of the duties that belong to each level.

3. Shifting the locus of responsibility over professional policy matters, such as the quality of teaching and learning, continuing training and development, the evaluation of practice, and systems for registration and accreditation of advanced skill, closer to teacher organisations.

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COMPARISON OF PERSONAL AND CLASS FORMS OF THE SCIENCE LABORATORY ENVIRONMENT INVENTORY

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ABSTRACT

Existing instruments in classroom environment research have limitations when subgroups are investigated or case studies of individual students conducted. This study reports the validation and development of a personal form of the Science Laboratory Environment Inventory which is better suited to such studies. Further, systematic differences between scores on the class and personal forms of the instrument are reported along with comparisons of their associations with inquiry skill and attitudinal outcomes.

Science educators are increasingly questioning the effectiveness of science laboratory instruction (Klainin, 1988; Hofstein & Lunetta, 1982; Pickering, 1980) and students have also often commented that they do not see the laboratory as an effective method of instruction (Johnstone & Wham, 1982).

Considerable interest has been shown by researchers in the last two decades in conceptualising, measuring and investigating perceptions of the psychosocial environment of science classrooms (Fraser, 1986; Fraser & Walberg, 1991). They have also shown dimensions of these environments to be associated with both cognitive and attitudinal outcomes (Haertel, Walberg & Haertel, 1981) and that exemplary teachers generally have more positive learning environments in their classrooms (Fraser & Tobin, 1989). These studies have not related directly to the science laboratory environment and have therefore been unable to provide guidance for the improvement of that instructional setting.

An instrument for assessing the science laboratory learning environment was recently developed and validated in a cross-national study involving six countries (Fraser, Giddings & McRobbie, 1991). The Science Laboratory Environment Inventory (SLEI) assesses the dimensions of the learning environment in laboratory classrooms shown in Table 1 by asking students for their perceptions of their actual and preferred environments using a Likert type scale. This table also shows an example of an item from each scale and the scale category on the Moos' classification (Moos, 1974).

TABLE 1
DESCRIPTIVE INFORMATION FOR EACH SCALE

Scale Name	Moos Category	Description	Sample Item Personal Form
Student Cohesiveness	R	Extent to which students know, help and are supportive of one another.	I get on well with students in this laboratory class. (+)
Open-Endedness	P	Extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation.	In this laboratory class, I am required to design my own experiments to solve a given problem. (+)
Integration	P	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	I use theory from my regular science class sessions during laboratory sessions. (+)
Rule Clarity	S	Extent to which behaviour in the laboratory is guided by formal rules.	There is a recognized way of doing things safely in this laboratory. (+)
Material	S	Extent to which the laboratory equipment and materials are adequate.	I find that the laboratory is crowded when I am doing experiments. (-)

R: Relationship Dimension; P: Personal Development Dimension; S: System Maintenance and System Change Dimension.
Items designed (+) and scored 1, 2, 3, 4 and 5, respectively for responses Almost Never, Seldom, Sometimes, Often and Very Often. Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3.

PERSONAL FORM OF THE SLEI

Fraser and Tobin (1991) point out that there is potentially a major problem with nearly all existing classroom environment instruments when one comes to use them to identify differences between subgroups within a classroom (e.g., boys and girls) or in the construction of case studies of individual students. The problem is that items in current instruments are worded in such a way that they elicit an individual student's perceptions of the class as a whole, as distinct from that student's perceptions of his/her own role within the classroom. Although classroom environment scales have been used to advantage in case study research (Tobin & Fraser, 1987; Tobin, Kahle & Fraser, 1990), these studies underline the desirability of having new forms of instruments available which are better suited to this purpose than is the conventional Class form which has been used in recent research.

Accordingly, a Personal form of the SLEI which parallels its Class form was developed. Table 2 shows how the wording differs for items in the Class form and the Personal form of the actual version of the SLEI. In addition to making this Personal form available to researchers interested in individual or subgroup perceptions, this work makes it possible to investigate any systematic differences between the Class and Personal forms in terms of student scores or between the magnitudes of associations between achievement and environment.

TABLE 2
DIFFERENCES IN THE WORDING OF ITEMS IN
THE CLASS FORM AND THE PERSONAL FORM

Scale	Class Form	Personal Form
Student Cohesiveness	Students are able to depend on each other for help during laboratory classes. (+)	I am able to depend on other students for help during laboratory classes.(+)
Open-Endedness	In our laboratory sessions, different students do different experiments.(+)	In my laboratory sessions, I do different experiments than some of the other students.(+)
Integration	The laboratory work is unrelated to the topics that we are studying in our science class.(-)	The laboratory work is unrelated to the topics that I am studying in my science class.(-)
Rule Clarity	Our laboratory class has clear rules to guide student activities.(+)	My laboratory class has clear rules to guide my activities.(+)
Material Environment	The laboratory is crowded when we are doing experiments.(-)	I find that the laboratory is crowded when I am doing experiments.(-)

(+) These items are scored 1, 2, 3, 4 and 5, respectively, for the responses Almost Never, Seldom, sometimes, Often and Very Often.
(-) These items are scored 5, 4, 3, 2 and 1, respectively, for the responses Almost Never, Seldom, Sometimes, Often and Very Often.

Validity of Personal Form

The Personal form of the SLEI was administered along with the Class form as part of a larger study of senior high school chemistry classes in Queensland. This included both the actual and preferred version of each form as described in the introduction. At this time the sample of available responses to the Personal form consisted of 345 students in 60 classes in 33 schools.

Information about the internal consistency and discriminant validity of the actual and preferred versions of both the Personal form and Class form is reported in table 3. The data for the class form was from 1480 students in fifty-five schools in the larger study which was previously used to validate the class form (Fraser, Giddings & McRobbie, 1991). This table shows that the values of the alpha reliability and mean correlation of a scale with the other scales are very similar for the Personal and Class forms, thus attesting to the validity of the Personal form. Also, separate factor analyses of the actual and preferred versions, using the individual as the unit of analysis, confirmed that the Personal form had the same five-factor structure as the Class form. The amount of the total variance extracted was approximately 47% for the actual form and approximately 46% for the preferred form. Further, a series of ANOVAs for the actual version confirmed the ability of each scale in the Personal actual form to differentiate between the perceptions of students in different classrooms.

TABLE 3
INTERNAL CONSISTENCY (CRONBACH ALPHA RELIABILITY) AND DISCRIMINANT VALIDITY (MEAN CORRELATION WITH OTHER SCALES) FOR CLASS AND PERSONAL FORMS AND FOR ACTUAL AND PREFERRED VERSIONS

Scale	Form	Alpha Reliability		Mean Correlation with Other Scales		Difference between Class and Personal Means (Standard Deviation Units)	
		A	P	A	P	A	P
Student Cohesiveness	Class	0.80	0.73	0.28	0.39	0.07	0.29**
	Personal	0.78	0.71	0.33	0.35		
Open-Endedness	Class	0.64	0.60	0.14	0.13	0.26**	0.38**
	Personal	0.66	0.60	0.14	0.14		
Integration	Class	0.85	0.81	0.30	0.33	0.31**	0.22**
	Personal	0.87	0.84	0.39	0.37		
Rule Clarity	Class	0.71	0.69	0.24	0.25	0.02	0.01
	Personal	0.72	0.68	0.39	0.32		
Material Environment	Class	0.68	0.60	0.32	0.38	0.14*	0.28**
	Personal	0.75	0.72	0.36	0.39		

*p<0.05, **p<0.01

Differences Between Scores on the Class and Personal Forms

One of the interesting questions which can be asked about the Personal form is whether the scores which the students obtain on this form vary systematically from those obtained using the Class form. This question was explored for a preliminary sample of 279 students who had responded to both the actual and preferred versions of the Class form and also to the actual and preferred versions of the Personal form.

Table 3 reports the magnitude of the differences between the means for Class and Personal forms expressed in standard deviation units. Information is provided separately for actual and preferred versions. Although the magnitudes of most of the differences are not particularly large (ranging up to 0.38 standard deviations), nevertheless the direction of all of the differences is consistent. In every case, the mean for the Personal form is lower than the mean for the Class form for both the actual and preferred versions. Moreover, t tests for dependent samples indicated that these differences were statistically significant for three scales for the actual version and for four scales for the preferred version ($p<0.05$).

Past studies comparing the perceptions of actual Class environment held by students with those held by their teachers in the same classrooms (e.g., Fisher & Fraser, 1983) consistently have shown that teachers hold more positive views of the classroom environment than do their students. That is, it appears that the different role which teachers play within the classroom enables them to be more detached about the classroom and therefore to see it more favourably. It is interesting to note that, in the present study, there is some evidence to suggest that scores on the Class form of the SLEI were more favourable than corresponding scores of the Personal form. This finding, that students seem to have a more detached and positive view of the environment as it applies to the class as a whole (Class form) than when the focus is on the student's own role within that classroom environment (Personal form), is consistent with the pattern in which teachers perceive classrooms more favourably than their students.

CAMPARISON OF OUTCOME-ENVIRONMENT ASSOCIATIONS FOR CLASS AND PERSONAL FORMS

In addition to the Personal and Class forms of the SLEI, the study also involved the administration of some student outcomes measures. The main purpose of the analyses reported in this section was to ascertain whether the Class and Personal forms differ in terms of the strength of their associations with student outcomes.

The cognitive outcome instrument used assessed chemistry-related inquiry skills and was based partly upon Fraser's (1979) Test of Enquiry Skills, an item bank (Australian Council for Educational Research, 1978) and items written by the authors. Factor analyses revealed that two factors accounting for 21% of variance could be extracted. The two factors were labelled Experimental Design, and Conclusions and Interpretation. The first scale contains 13 multiple-choice items and was found to have a KR-20 reliability of 0.70 for a sample of 170 students. The Conclusions and Interpretation scale has 12 items and a reliability of 0.79 for the same sample.

Affective outcomes were assessed with a Likert-type questionnaire covering a range of chemistry-related attitudes. This instrument was based partly on the Test of Science-Related Attitudes (Fraser, 1981), partly on other scales assessing the testability and changing nature of science (Rubba & Andersen, 1978) and partly on items written by the authors. Factor analyses of this pool of items resulted in the emergence of five factors which extracted approximately 42% of the total variance. The names of these five factors, together with an estimate of each scales alpha reliability coefficient (estimated for a sample of 109 students) were as follows: Enjoyment of Chemistry (reliability: 0.91), Adoption of Laboratory Scientific Attitudes (0.85), Attitude to Laboratory Learning (0.84), Cooperative Learning (0.90) and Nature of Chemistry Knowledge (0.80).

A matrix sampling plan was employed so that different instruments within the total battery were answered simultaneously by different random subgroups of students within each class. For example, some students responded to the inquiry skills outcome measure, while others responded to the attitude instrument. While some students responded to the Personal form of the SLEI, others responded to other instruments which are not considered in this paper. The samples used for the present comparison of the predictive validity of the Class and Personal forms consisted of those students who, had available

(1) scores on either the inquiry skill or attitude posttest,
(2) scores on the corresponding pretest and a general aptitude measure,
(3) responses to the Personal actual form and
(4) responses to the Class actual form.

The resulting samples comprised of 170 students with responses to the inquiry measure and 109 students with responses to the attitude measure. As the data collection process is still in progress, larger samples and more conclusive analyses involving class means will be available at a later time. Consequently, caution is recommended when interpreting the findings reported in this section.

In table 4, four different statistics are used to describe the strength of the association between the set of five SLEI scales and each of the seven student outcomes, and to compare the Class and Personal forms in terms of the strength of this association. First, the simple correlation (r) is reported between each outcome and each environment scale. Second, the semipartial correlation (sr) between each outcome and each environment scale is reported when both the corresponding pretest score and the general aptitude measure were controlled; these partial correlation analyses are more conservative than the simple correlation analyses because they rule out the alternative explanation that observed outcome-environment relationships can be explained simply in terms of differences in student pretest performance and general ability. Third, the multiple correlation (R) between each outcome and the whole set of five environment scales is reported at the bottom of the table. Fourth, the semipartial multiple correlation (sR) is reported at the bottom of Table 8 to reflect the magnitude of the multiple correlation between each outcome and the set of environment scales when both corresponding outcome present and general ability are controlled. The square of the semipartial multiple correlation is equal to the proportion of variance in an outcome measure uniquely attributable to the set of SLEI scales beyond that accounted for by corresponding pretest and general ability scores (Cohen & Cohen, 1983).

TABLE 4

A COMPARISON OF CLASS AND PERSONAL FORMS OF THE SLEI IN TERMS OF THE SIMPLE (r), SEMIPARTIAL (sr), MULTIPLE (R) AND SEMIPARTIAL MULTIPLE (SR) CORRELATION WITH SEVEN COGNITIVE AND ATTITUDINAL OUTCOME MEASURES.

Strength of Outcome-Environment Association

Environment	Form	Experimental Design		Conclusions and Interpretations		Enjoyment of Chemistry		Adoption of Scientific Attitudes		Attitude to Laboratory Learning		Cooperative Learning		Nature of Chemistry Knowledge	
		r	sr	r	sr	r	sr	r	sr	r	sr	r	sr	r	sr
Student Cohesiveness	Class	.07	.07	.11	.08	.37**	.35**	.35**	.45**	.48**	.47**	.35**	.35**	.21*	.24*
	Personal	.13	.05	.24**	.21**	.36**	.08	.35**	.01	.38**	.03	.35**	.09	.18	.03
Open Endedness	Class	.10	.12	.18*	.13	.13	.30**	.11	.36**	.02	.41**	.11	.13	.01	.38**
	Personal	.08	.06	.26**	.26**	.11	.19*	.04	.29**	.01	.25**	.04	.16	.05	.05
Integration	Class	.15*	.12	.21**	.18*	.29**	.10	.12	.26**	.45**	.24*	.12	.29**	.39**	.30**
	Personal	.22**	.07	.29**	.27**	.30**	.37**	.22*	.35**	.41**	.37**	.22*	.34**	.26**	.18*
Rule Clarity	Class	.05	.11	.04	.07	.20*	.11	.16	.01	.25**	.01	.17	.03	.10	.03
	Personal	.07	.29**	.19*	.13	.35**	.33**	.29**	.35**	.42**	.38**	.29**	.20*	.17	.24
Material Environment	Class	.03	.01	.04	.04	.14	.35**	.30**	.30**	.25**	.43**	.30**	.23*	.30**	.16
	Personal	.03	.05	.12	.12	.25**	.19*	.26**	.27**	.25**	.25*	.26**	.24*	.19*	.21*
Multiple Correlation, R	Class	.21		.27*		.47**		.53**		.56**		.42**		.34**	
	Personal	.24		.37**		.46**		.42**		.51**		.42**		.22	
Semipartial Multiple Correlation, sR	Class		.20		.17		.25		.51**		.53**		.30*		.41*
	Personal		.35**		.25*		.25		.40**		.47**		.30*		.26*

* $p < .05$,
** $p < .01$

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In terms of the relative strength of the associations of outcomes and students' perceptions of the actual environment on the Class form and the Personal form of the SLEI, overall no clear pattern emerges from the analyses reported in Table 4. That is, the Class form and the Personal form cannot be differentiated in terms of the relative strength of the relationship existing between students' outcomes and their perceptions on the actual version of the SLEI.

Nevertheless, the results reported in this table provide considerable support for the predictive validity of both the Class and Personal forms of the SLEI individually. The associations found between student outcomes and classroom environment replicate considerable prior research (Fraser, 1986).

CONCLUSION

This study contributes to the field of learning environment research in the development and validation of a Personal form of the Science Laboratory Environment Inventory to parallel the more conventional Class form. This new form will be more suitable for use in learning environment research, especially where subgroups or case studies of individuals are involved. Further, preliminary results suggest that students' personal perceptions were less favourable than their perceptions of their class laboratory environment and that, as in past research in classroom settings, the dimensions of the laboratory learning environment were significantly related to cognitive and attitudinal outcomes commonly associated with laboratory instruction work. The nature of these relationships should be probed with further qualitative and quantitative studies to further elaborate how these dimensions of the laboratory environment relate to outcomes and to assess their potential in monitoring and improving laboratory instruction.

Copies of the Class form and Personal form of the Science Laboratory Environment Inventory are available from Dr G Giddings.

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THE ROLE OF LANGUAGE IN SCIENCE EDUCATION: SOME REFLECTIONS FROM FIJI

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ABSTRACT

One of the issues identified in a recent study of science teaching and learning in Fiji's primary and secondary schools was the problems faced by students in coping with scientific terminology, and in expressing ideas in their own words (Muralidhar, 1989). In this paper, some examples from the study are used to illustrate the extent of the problem and to discuss the implications for teaching and learning science. It is argued that the quality of communication is an important factor in promoting the understanding of science, especially when the main sources of information for the majority of students are the textbook and the teacher.

INTRODUCTION

In recent years, a number of studies have addressed the complexity of the language of science in the classroom. If we pause a little and think of what the majority of pupils has to cope with in science lessons, we will then begin to understand the background to this complexity. The pupil has to cope with: his or her own language while writing notes or completing homework; teacher's spoken language; the language used in curriculum materials and textbooks; teacher's written language on the chalkboard, handouts and tests; the terminology of science; and the disparity between the meanings of the same words when used in everyday language and when used in the context of a science lesson.

Some of these issues have been explored by scholars in the context of native speakers of English (Barnes, 1969; Bell & Freyberg, 1985; Gardner, 1974, 1977; White, 1988). These studies show that even students whose mother tongue is English experience difficulties in dealing with the specialist terminology used in science and in coping with the language demands and assumptions made by science teachers and writers of curriculum materials. This being the case, the problems faced by students learning science in a second language are bound to be even greater and more complex.

To illustrate the difficulties experienced by native English-speaking pupils in coping with scientific terminology used in textbooks and examinations, Greenwood (1990) cites two examples:

* In a study of the language of O-level chemistry, only five percent of the pupils could correctly use terms such as: pungent, justify, attributed, dense, concept, residue, converse, constituent.

* Of the pupils who answered the following question, only 34 percent gave the correct response:

Which one of the following requires a non-aqueous solvent to dissolve it?

a) salt c) sodium nitrate
b) sugar d) sulphur

But when the question was changed to "Which one of the following requires a liquid other than water to dissolve it?", 49 percent of the pupils in a comparable group gave the correct response. Thus, just by replacing the term "non-aqueous" in the question, the success rate improved by 15 percent.

We can think of a number of instances in science, and even in other subjects, where pupils' failure to respond correctly to a question is mistakenly attributed to their lack of understanding of the concept. To a large extent, this is a result of the disparity between the language used by the teacher of science and the language used and understood by the pupils. Very often teachers take it for granted that the language used to state rules, express concepts or define terms is self-evident, and may fail to notice that what seems simple and clear to them may be hard and vague to their pupils.

THE FIJIAN CONTEXT

The above examples were cited to emphasise that it is not just the non-native speaker of English who has difficulties with the language of science and that the language needs for learning science are more than simply the acquisition of an adequate level of general English. Before moving on to illustrations from science lessons in Fiji, a brief outline of the structure of schooling in Fiji is in order.

The main languages spoken in Fiji are Fijian, Hindi and English. Except for the initial years of the primary school, the medium of instruction at all other levels is English, and it is also a compulsory subject of study. Students also have the opportunity to study Fijian, Chinese, Hindi and other Indian languages at primary and secondary levels.

Children in Fiji enter the first year of the primary school at a minimum age of five years and eight months, and follow successive stages as shown below. In some schools, years 7 and 8 are the last two years of the primary system, while in others, they are the first two years of the secondary system.

(Primary)
Year/Grade: 1 2 3 4 5 6 7 8

Year/Grade: 7 8 9 10 11 12 13
(Secondary)

The science curricula presently followed in Years 1-13 were all developed locally, and are as follows:

* Years 1-6	Elementary Science (Primary)
* Years 7-10	Basic Science (Primary/Secondary)
* Years 11-13	Choice of Physics, Chemistry, Biology (Secondary)

The data I present below came from observations of more than a hundred science lessons spread over the whole range of grades, and from interviews with students and teachers, carried out in 1988.

ILLUSTRATIONS FROM SCIENCE LESSONS

A Question without words

Figure 1 shows a question given in a Basic Science test for Year 7 students.

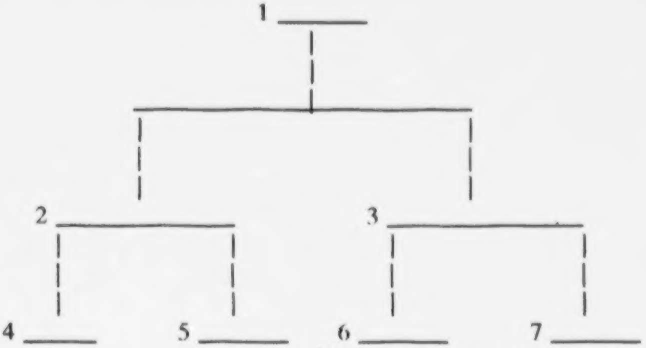

Fig.1 Question on test paper

When I looked at the question I had no idea of what the students were supposed to do; the question did not have any statement or instructions. But when I went round the class I discovered that students knew what they were supposed to fill in: 1 Substances, 2 Living, 3 Non-living, 4 Plants, 5 Animals 6 Natural, 7 Man-made. I then realised the conditioning the students had gone through; they could respond to questions even without statements. The teacher casually told me that her pupils knew what to write in the blank spaces.

When the teacher was going over the answers to the question, she asked the class for an example of a natural object. One student mentioned "grass", but this example did not fit into the classification system given in the book which divided living things into plants and animals, and non-living things into natural and man-made. Therefore "grass" could not be identified as a natural object; the answer was not acceptable to the teacher. One can only speculate about the confusion caused in the mind of the young student.

When I was speaking to the teacher a couple of weeks later, I asked her if she was justified in rejecting the student's answer. After some discussion she realised her mistake and undertook to bring it up in the class.

Words Do Matter

In a Year 7 class, a teacher wrote the following questions on the board and asked the pupils to answer them in their books:

1. Explain what is matter?
2. Name the three states of matter
3. Write one sentence for each to describe the difference between solid liquid and gas [sic].
4. Classify these substances into solid, liquid and gas. Stone, foam, plastacine [sic], beer, rubber, air, hair, smoke, water, paper, lemon juice, oxygen.
5. In which state of matter are [sic] able to move about most freely [sic] solid, liquid or gas.

When I went round the class to see what the students were writing, I discovered that they were having difficulties, particularly in answering questions 1, 3 and 4. In answering Question 1, they were trying to reproduce the standard statement "Matter is anything that occupies space and has weight". Many did not know what "occupies" meant; they were also struggling with the spelling of the word. This is how they spelt "occupies":

occupis, ocours, ocopaises, oxpaiyea, octopases, octopaseds, occurpies, occupiece, occupic, ocipies, occuprece, occypies, occpic, occpiss, occupuis

In Question 3, some students had difficulty understanding the question while others struggled to frame sentences. In questions 4, the term "classify" posed a problem for a number of students. Only towards the end of the period did the teacher realise that something was missing in Question 5, and inserted "the particles" between "are" and "able". I am not sure if it made any difference to the students.

What the students were going through graphically demonstrated to me the barrier created by terminology; the very terminology taken for granted by science teachers. I was not able to find out what effect students' responses had on the teacher or how he reacted to them. But what came out clearly was that the teacher was oblivious to the difficulties students were having in answering the hastily written questions.

One of the questions in a test given to a Year 7 Class was:

Explain the following terms:

(a) soluble (b) insoluble (c) solvent (d) solute

Of the 34 students who took the test, only 12 answered all the four parts and 16 did not attempt any part. The following are the 12 responses to part (d):

* the solvent that dissolves
* mean somthing that dissolve in solid
* the solute that dissolve in solvent
* means anything that dissolves in solid
* something hard
* mean when something can dissoved in water
* something were dissolve in solid
* is something that dissolve in solution
* something con dissvels in solvent
* had something like solvent
* is something hard
* solid did not barn

Of the eight students who tried to use the word "dissolve", only three used the word in a scientific way. Once again, the responses indicate the complexity of the language of science and the problems our students face in understanding and expressing the meanings of technical terms. An additional concern is that 16 students in the class did not respond to the question at all. Perhaps they did not know what to write; one can only speculate. It seems to me that instead of asking younger students to "define" and "explain" terms, teachers need to think of better ways of testing the understanding of scientific terminology.

It might be argued that the use of specialised terms is basic to the study of science, and without them the subject would lack the necessary linguistic means to exist (Greenwood, 1990). While there is some justification in the claim, students will have very little understanding of the terms and definitions introduced in science lessons unless they have clear and relevant examples in their minds.

Teachers' Questions and Students' Responses

In the majority of lessons I observed, the main function of the questions asked by teachers was to test for pupils' ability to recall facts. Questions were largely convergent in nature, and because of this, students' responses were restricted to one or two words, completing teachers' statements, or to saying yes/no. Even where questions required some thinking to be done, students were not given time to process information and formulate the answers. The following extract from a lesson transcript illustrates this point:

T: Now, do you think decomposers can photosynthesise? decomposers - can they photosynthesise? or can they perform photosynthesis? yes or no?
S: no
T: no! just think. When the decomposers are breaking down dead decayed things or causing things to decay, what are they feeding on?
(without waiting for a response) the decayed matter, isn't it? dead decayed matter. So, if an organism feeds on dead decayed matter, do you think it is er...can photosynthesise? Shalini?
S: yes
T: Yes! they can't isn't it? because if they feed on dead things, they are not utilising sunlight, carbon dioxide and water. So, they cause decay and therefore feed on decaying matter. So they are not grouped or identified as green plants right? or producers.

(Year 9 Class)

Teachers were generally preoccupied with the "right" word, the "correct" answer or the "proper" definition, but very few attempted to explore how students arrived at a particular answer or whether they understood the meaning of the word or the definition.

T: (reads from the book) How do plants trap sun's energy? How do they trap it? What happens when the sun shines on the leaf? Salma? Alisi? You don't know! (a little annoyed) Rajeli?
S: photosynthesis
T: Yes - good - through photosynthesis

(Year 10 Class)

T: What is volume?
S1: To measure objects
S2: Amount of space taken by an object
T: Good boy

(Year 7 class)

T: Let's look at the answers to questions. Question one: when solid wax is heated, it_____. I had one blank here, one space to fill it in there, right? Yes Lepani?
S: changes to liquid
T: It changes to liquid. I got one space here - I have already gave [sic] marks to people, but anyone can tell me any better words apart from [this] - one word - yes?
S: it melted?
T: It melted, yes, or it melts, right? I was looking for
SS: melts, yes
T: When solid water is heated, it melted or it melts. This is the word - so if you have got this one, that is the best answer. Other people have written: it changed to liquid - I have given you half mark or something like that - right?

(Year 7 Class)

One-way Communication

Some teachers even did most of the "observations and "interpretations" for students, thus robbing students of the opportunity to express what they saw and did, in their own words. The following extract refers to a Class 7 activity in which hydrochloric acid is added to pieces of coral:

T: If your coral was very white and clean, you must have seen - you may have seen tiny pieces of coral breaking off and moving around in the test tube with the bubbles as it rose up - yes?
SS: yes
T: Okay - that means some sort of what was given off - bubbling off? bubbles must have been made of something.
SS: air, air
T: Air?
SS: gas, gas,gas
T: Gas - right? Air has many kinds of gases in it but what particularly must have been coming out of that test tube was
SS: gas
T: That means, pieces of coral must have been eaten away by the acid to form
SS: gas
T: gas - so, this definitely must be a chemical change.

In another lesson, the same teacher is discussing the heating of water in a beaker:

T: Okay - now - the [activity] we did in which we heated a beaker of water, we noticed [bubbles] of what coming out?
SS: bubbles

T: bubbles coming out - bubbles definitely were of
SS: air, air
T: that suggested that water has
SS: air, air
T: Air - when you heat it [water], it drives the air out - okay?
SS: yes

Activity-lessons in science provide excellent opportunities for teachers to encourage oral and written communication among pupils. But as these extracts show, teachers tend to have a monopoly on words and fail to know their students' thoughts and ideas. In the first extract, the teacher was certain that the "bubbles must have been made of gas", and in the second, that the "bubbles definitely were of air". But, for the pupils it was just "bubbles"; how would they know the difference?

Stress on Uniformity

The approach used by the majority of teachers did not encourage students to express their ideas freely. This was especially the case in primary schools where teachers wrote everything on the board for students to copy; the activities, the diagrams, the answers, and even the date. Pupils could write in their books only after the teacher was satisfied that they were clear about what to write. I became aware of the seriousness of the problem in the very first lesson I observed in the study. The teacher called on the students to read out their answers to some questions given for homework. After pointing out some of the errors, the teacher removed the cardboard sheet which was covering the answers she had written on the chalkboard earlier. The students immediately started erasing their answers and began copying teacher's answers from the board. When I questioned the teacher about this practice she said , " I have got the habit of marking each work they do, and so, if they all have the same answers, then the work is easier as far as the marking is concerned". She justified her actions by saying that her heavy teaching load and the large classes she was teaching did not allow her enough time to go through students' books in detail. This is only one of many such observations.

Another factor which inhibited students' self-expression is the design of the Basic Science curriculum materials. Most of the exercises and record of activities in Pupils' Books are in a pre-set format requiring students either to complete sentences or to fill in blanks. Likewise, the recipe-style and over-instruction adopted in Teachers' Books did not encourage teachers to move beyond the book and develop creative approaches suitable for their students. Because of their inadequate background in science, most primary teachers stuck rigidly to Teachers' Books and presented lessons, with very little variation.

Discouraging Students' Responses

In many lessons, students were ridiculed if their responses were not in agreement with what the teacher was looking for; it was as if the student was on trial for a grave crime. The following exchange took place in a Year 7 class during the lesson: Why is Sea Water Salty?

T: Where does the salt in the sea water come from? Think about it - put your hands down - where does the salt come from? Yes?
S1: comes from the washing
T: washing?
SS: no
T: comes from the?
S1: women washing the er...
T: (raising her voice) no - no - you are talking about fairy tales - we are not talking about fairy tales. We try and find the explanation for that ha? Fairy tales - no - no - we are not interested in fairy tales - this is not a English class - this is a science class ha?
SS: yes
T: we try and find out
SS: yes

To start with, this group of students had considerable difficulties reading and writing English. The attitude of this teacher made matters worse; the more she forced them to come out with responses, the more they shrank and withdrew - they were scared to open their mouths. "We try and find the explanation for that" was a pretence; this is how the students (and the teacher) found the explanation:

> Where does this salt come from? Discuss the following information. Minerals from rocks gradually get washed out by rain-water. Some minerals are in the soil and they dissolve in the rain-water which makes its way to the rivers and finally end up in the sea. These minerals which collect in the sea give it a salty taste.

(Basic Science 1, Teacher's Handbook, Form1/Class7, p. 41)

In a Year 9 Class, the teacher was asking students to name the compound SO_3. After various attempts by students, the teacher finally told them that it was sulphur trioxide. One student interjected by saying "triangle", and for this, he was admonished by the teacher: "This is a science lesson - we are not doing maths". The student was probably trying to relate the "tri" in "trioxide" and "triangle", but this was not appreciated by the teacher.

Science lessons provide excellent opportunities for developing the language skills in students, but as the above examples show, such opportunities are lost if teachers keep their minds closed. Terms used in science become more meaningful if students are shown how they are used in different contexts. Kulkarni, in discussing these issues in the Indian context, makes an important point:

> While the importance of improving language skills for better science education is being appreciated, the role science can play in improving language skills is not fully realized. Science is ideally suited to present the correct usage of various conjunctions .... Modern trends highlight science at the expense of language. What is needed is a boot-strap approach using science to introduce pupils to higher language skills which in turn could be used for better science education.
>
> (Kulkarni, 1988, p. 166)

DISCUSSION AND IMPLICATIONS

The few examples I have given and the comments I have made illustrate the problems faced by our primary and secondary students trying to learn science in a second language. The problems were more acute among students who come from rural communities because they are exposed to English only when they are in the classroom; the rest of the time they communicate in their mother tongue.

When I discussed students' language difficulties with teachers, they usually began their comments by saying, "the type of students we have got here", and complained about students' lack of background and ability. Very few teachers were genuinely concerned about the language difficulties of students; perhaps they already had enough to do, teaching science to their students. Some shifted the responsibility to their colleagues teaching English.

I came across only one instance where a teacher had attempted to respond positively to students' difficulties. He did this in several ways. For a start, he related well to his students by constantly encouraging them even when their responses were not satisfactory. Students felt free to speak without fear of being humiliated. He also encouraged students to speak in their mother tongue (Hindi or Fijian) when they were doing activities or discussing questions in groups. After all, many students use their mother tongue while talking to their friends even inside the classroom. This teacher wanted to see if the experiment would help his students to understand the ideas better. He also gave the following advice to his students which I thought made sense in any context:

> Whenever you are going to define anything in [a] science lesson, it is better to give an example though the question doesn't say give an example...because if you are wrong in the definition, at least some marks will be given for your example. You will tell the examiner, this is what I am talking about - I might be wrong in my explanation but this is the example I am quoting.

Genuine and deliberate effort is needed both at the system level and at the classroom level to improve the language skills of students. Teachers need to be made aware of the importance of language in science education through regular workshops and courses. In our situation where for the majority of students the only sources of information are the teacher and the textbook, the quality of communication becomes even more important in promoting the understanding of science. Teachers and curriculum designers need to pay greater attention to how ideas are communicated to students and how ideas are received from students. Pupils need to be given more opportunities and encouragement to communicate their thinking both orally and in writing. After all this is one of the stated aims of the Basic Science Curriculum:

> 5. [T]he course is designed to develop the ability to work with others, communicate and share ideas and to recognise and appreciate the points of view of other people.
>
> (Ministry of Education, Youth & Sport, 1976, pp. 1-2)

Teachers also need exposure to strategies that might be useful in realising this aim with their students.

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THE CONCEPT MAPPING HEURISTIC AS VIEWED BY SOME AUSTRALIAN AND INDONESIAN SCIENCE TEACHERS

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ABSTRACT

This paper reports a study on concept mapping involving 14 Australian and 9 Indonesian science teachers. After a training and practice session in concept mapping, the teachers were surveyed on four scales: "Learning it", "Teaching it", "Useability by students", and "Perceived benefits". While the teachers' attitudes were generally favourable interesting differences were discerned among scales, among teachers of Biology, Chemistry, Physics and Mathematics, and between countries.

INTRODUCTION

Walberg (1991), in a review of science education practices and expectations in advanced and developing countries, echoed the thoughts of science educators about the importance of improving school science. The overriding goal of efforts at improving school science is improvement in students' performance. Performance indicators are those attitudes and skills that students manifest following exposure to learning experiences in science (Colburn & Penick, 1991). The science education literature is replete with evidence showing that these attitudes and skills are enduring if meaningful, rather than rote, learning is allowed to prevail in science classes (see review by Koballa, Crawley & Shrigley, 1990).

Meaningful learning occurs when concepts are fully assimilated into the cognitive structure, and metacognition is attained. Three tools have recently been devised to assist learners attain metacognition and help improve performance in school work: Concept mapping, vee diagramming and concept-circle diagramming. Concept mapping was invented in 1972 by Joe Novak and his associates. In 1977, Bob Gowin followed up this effort by devising the vee-diagramming technique. Concept-circle diagramming was proposed in 1984 by Jim Wandersee.

Of the three, concept mapping has enjoyed the greatest research attention. It is a procedure for helping students organise concepts (which are ordered information about properties of objectives, events or processes, designated by an arbitrary label) into meaningful, as opposed to loosely connected, entities. A concept map depicts relationships among concepts. It is based on the premise that concepts do not exist in isolation but depend on others for meaning. For example concepts like ultrafiltration and selective reabsorption do not exist in isolation. They can be called subordinate concepts that are connected to the superordinate concept of osmoregulation (Note 1).

In a lesson in which concept maps will be used, students are requested to list the main words, phrases, or ideas or concepts that are mentioned or discussed with respect to the topic for that lesson. In a 90-minute demonstration lesson on photosynthesis, students listed an average of sixty-two such concepts, key words, phrases and ideas (Okebukola &

Jegede, 1989). There is of course, no minimum or maximum, as each student is expected to write down words, phrases and ideas that are considered 'key' from the perspective of that student. Experience has however, shown that variation in the number of such concepts, key words, phrases or ideas (concepts) among students in the same teaching-learning condition, is small.

Towards the end of the lesson, students rank the list of concepts and main ideas from the most abstract and inclusive to the most concrete and specific. The concepts are then clustered according to two criteria: concepts that function at a similar level of abstraction, and concepts that inter-relate closely. The concepts are subsequently arranged as a two-dimensional array, analogous to a road map. Each concept, is in effect, a potential destination for understanding. Its route is defined by other concepts in the neighbouring territory. Related concepts are then linked with lines and the phrases in the list used as labels for each line in a propositional or prepositional form.

The development of the concept-mapping strategy was based on Ausubel's (1968) assimilation theory which is based on the principle that the single most important factor influencing learning is what the learner already knows. Concept maps are diagrams indicating interrelationships among concepts as representation of meaning or ideational frameworks specific to a domain of knowledge (Novak, 1990b). The maps can be applied to any subject matter and to any level within the subject. Maps generated by a learner reports his or her conceptual organization of the topic (Schmid & Telaro, 1990). As stated by Novak (1990b):

> the meaning of any concept for a person would be represented by all of the propositional linkages the person could construct that include that concept. Since individuals have various sequences of experiences leading to unique total sets of propositions, all concept meanings are to some extent idiosyncratic.

Student-constructed maps involve subsumption because the learner constantly uses new propositions to elaborate and refine concepts that he or she already knows (Schmid & Telaro, 1990). Progressive differentiation therefore occurs as a result of integrating information into a progressively more complex conceptual framework.

The Problem

The first comprehensive study on concept maps by the inventor of the technique was conducted in 1982 (Novak, Gowin & Johansen, 1983). Since then, many researchers have found this line of inquiry to be profitable in their quest for an antidote to rote learning of science concepts. An attestation to the potential of the concept-mapping heuristic to science education is seen in having a special issue of the Journal of Research in Science Teaching (Vol. 27 No. 10) devoted to reporting research on the technique.

Concept maps have been shown to bring about meaningful learning of science concepts (Novak, 1990b; Okebukola, 1990; Okebukola & Jegede, 1989), help reduce anxiety level in science classes (Jegede, Alaiyemola & Okebukola, 1990; Okebukola & Jegede, 1989), reduce topic difficulty (Note 2, Okebukola & Jegede, 1989) and improve students' problem-solving skills (Note 1). In a review of 100 references related to concept mapping, evidence was shown that is being used for instructional design and evaluation, classroom instruction, probing of thought processes and the identification of students' misconceptions in science (Al-Kunifed & Wandersee, 1990). It is intriguing to note that the literature on the disposition of teachers towards the tool is sparse.

The attitude of teachers towards a teaching technique is a potent variable in determining the use of that technique. (Koballa et al. 1990). If teachers are well disposed towards an innovation like concept mapping, the chance of bringing about meaningful learning of science concepts will be improved.

However, none of the 100 references listed by Al-Kunifed and Wandersee (1990) focused on teachers' attitudes. An extensive literature search also failed to reveal studies in this area. An effort to fill this gap in the literature was undertaken by Okebukola (Note 3). In that study, the views of 141 biology, chemistry, physics and mathematics teachers in Nigeria were sought on the concept-mapping and vee-diagramming techniques. The present study replicated this initial effort with Australian and Indonesian teachers.

The problem that this study addressed was to find out the views of science and mathematics teachers in Australia and Indonesia on concept mapping. Four aspects were surveyed: (1) Learning how to make concept maps by teachers; (2) teaching concept mapping to students; (3) Useability by students; and (4) Perceived benefits of the heuristic.

METHOD

Sample Fourteen Australian and nine Indonesian science and mathematics teachers were involved in the study. These teachers participated in workshops organised by the authors. The teachers had from 5 to 24 years experience. There were 8 biology, 7 chemistry, 4 physics and 4 mathematics teachers in the sample.

Instrumentation The views of the teachers were sought using the Attitude towards Concept Mapping Inventory (ACMI). ACMI was developed and factorially validated (Note 3). It measures the attitude of teachers towards concept mapping as a metacognitive tool in science and mathematics. It has 16 items (eight positively stated and eight negatively stated) on a 5-point Likert scale. Scoring was 5,4,3,2, and 1 for positive items, with scoring reversed for negative items. There are four subscales on the inventory. These subscales are: (1) Learning it (items 1, 13, 14 and 16); (2) Teaching it (items 3,9,11 and 12); (3) Useability by students (items 2,4,5 and 8) and (4) Perceived benefits (items 6,7,10 and 15). Scale reliabilities range between .82 and .89. Alpha for the whole inventory is 0.87.

Procedure The science and mathematics teachers in the sample had lecture/discussion sessions on concept mapping in two groups (Australian and Indonesian). After this, group members had practice sessions on making concept maps. A teacher from each of the four subject areas then made a presentation of a concept map for review by the whole group. Suggestions for improving the map was given by members of the group. Towards the end of the workshop sessions, discussions were held on ways of deriving more benefits from using concept maps in teaching science and mathematics. The participating teachers responded to ACMI immediately after the workshop as a way of finding out their views in the four areas.

DATA ANALYSIS AND FINDINGS

Three sets of mean and standard deviation scores were determined from the ACMI data obtained from the sample. The first set was for each of the 16 items for the four subject groups of teachers. The second set was for each of the four scales ACMI for the four groups of teachers as well as for the teachers pooled together. The third set was for the total score on ACMI by teacher group.

In reporting the findings of the study, we settled for a global-to-specific procedure. From a global perspective, we found on the basis of the third set of mean scores, that all the four groups of teachers had mean scores above 3.0, indicating a favourable attitude towards concept mapping. The biology teachers had the highest overall mean score and the mathematics teachers the least (Table 1). No significant inter-group mean differences were found. The Kruskal-Wallis one-way ANOVA H-test, suitable for comparing small samples, was employed.

TABLE 1
MEANS AND S.D. OF TOTAL ATTITUDE SCORE BY TEACHER GROUP

	BIOLOGY	CHEMISTRY	PHYSICS	MATHS
N	8	7	4	4
Mean	4.15	4.00	3.91	3.76
S.D.	0.98	0.91	0.85	0.59

Note: Kruskal-Wallis "H" is not significant (p> .05)

Turning next to the four scales, data in Table 2 show no significant differences in the mean scores of the four groups of teachers in their perception of learning and teaching concept mapping, useability by students and the perceived benefits of the heuristic.

TABLE 2
MEANS AND S.D. OF ATTITUDE TO CONCEPT MAPPING SUBSCALE SCORES BY GROUP

Subscale	All (N=23)	Biology (N=8)	Chemistry (N=7)	Physics (N=4)	Maths (N=4)	Sig. of "H"
1. Learning it	4.02	3.97 (0.91)	4.31 (0.92)	4.17 (0.92)	3.62 (0.62)	ns
2. Teaching it	3.90	4.10 (0.98)	4.23 (0.94)	3.65 (0.79)	3.62 (0.58)	ns
3. Useability	3.71	4.14 (0.96)	3.44 (0.84)	3.71 (0.82)	3.56 (0.59)	ns
4. Benefits	4.15	4.25 (0.99)	4.00 (0.86)	4.09 (0.90)	4.25 (0.51)	ns
Sig. of "H"		ns	ns	ns	ns	

ns = not significant

For the top group, "Perceived benefits" had the highest mean score and "Useability by students" the least.

Table 3 reports the means and standard deviation values for the four groups of teachers on the 16 items. No significant differences were found in the perception of teachers in 13 of the 16 items. The mean scores for item 4 "Using it takes too much of class time", item 11 "I will find it difficult to teach my students" and item 16 "I learnt the use of the strategy within an hour of being taught", were significantly different. For item 4, the physics and mathematics teachers' mean scores were found to be lower than the biology and chemistry teachers' scores. For items 11 and 16, the mathematics teachers had the lowest mean scores.

After a critical review of the concept-mapping procedure, the teachers agreed that adding formulae, worked examples and drawings would help to enrich concept maps produced by students.

DISCUSSION

The primary goal of this study was to seek the views of some Australian and Indonesian science and mathematics teachers on the use of concept mapping as a metalearning tool in science. The findings are consistent with those of an earlier study (Note 3) which surveyed 141 Nigerian teachers on both concept mapping and vee diagramming.

The biology teachers expressed the most favourable opinion of the groups of teachers; the mathematics teachers the least. This finding could be explained using information gleaned from post-workshop discussions. While the biology, chemistry and physics teachers found it relatively easy to categorise concepts into subordinate and superordinate, the mathematics teachers in the sample had a little difficulty making this classification with some mathematical concepts. There was some debate, for example, about whether "a point" should be classified as a superordinate or a subordinate concept. In the Nigerian study (Note 3) the mathematics group consistently recorded the lowest mean attitude scores for both concept mapping and vee diagramming. Some mathematics educators who had used concept maps conclude that it can be a little problematic when used in mathematics teaching.

Four aspects of the concept-mapping heuristic were also of interest in this study. First, is the ease with which science and mathematics teachers can learn the concept-mapping technique. The relatively high mean scores on the "Learning it" scale indicate that the teachers in the sample perceived little difficulty with learning concept maps. Of note however, is the low mean score (2.00) of the mathematics teachers on the item "I learnt the use of the strategy within an hour of being taught". This score falls within the "Disagree" category. It is unclear why the mathematics teachers, out of the four groups of teachers, found difficulty with learning concept mapping. Novak (1990a) and Wandersee (1990) believe that concept mapping is a technique that even grade 4 pupils are able to learn in a minimum amount of time.

Other teachers did not perceive the teaching of concept mapping to be problematic. Of the four aspects, the benefits of concept mapping stood out to be the most favoured by the teachers. High mean scores were recorded for such items as "Using the strategy can reduce the anxiety level of students in my subject". This supports the data provided by studies on the influence of concept mapping on students' performance in science and mathematics (see reviews by Novak, 1990a; Okebukola, 1991; Wandersee, 1990).

TABLE 3
MEANS, STANDARD DEVIATIONS AND KRUSKALL-WALLIS TEST ON ITEM SCORES OF THE FOUR GROUPS OF TEACHERS ON THE ATTITUDE TOWARD CONCEPT-MAPPING

STATEMENTS	Biology (N=8)	Chemistry (N=7)	Physics (N=4)	Maths (N=4)	Sig.of H
1. Concept mapping is easy to learn.	4.78 (0.98)	3.75 (0.62)	4.33 (0.77)	4.00 (0.65)	ns
2. It can provide an exciting activity for the class	4.10 (0.99)	3.50 (0.73)	3.91 (0.82)	4.25 (0.96)	ns
3. Students will dread being asked to make concept maps.	3.89 (0.76)	3.67 (0.87)	3.08 (0.59)	3.00 (0.79)	ns
4. Using concept maps can take too much of class time.	4.28 (0.88)	3.00 (0.87)	2.83 (0.81)	2.75 (0.84)	$p<.05$
5. It can be used by students for any topic in my subject.	4.00 (0.79)	3.75 (0.92)	4.41 (0.81)	4.25 (0.69)	ns
6. The claim about its bringing about meaningful learning is apparently true	4.50 (0.88)	4.00 (0.69)	4.33 (0.77)	4.50 (0.81)	ns
7. Using the tool can make students be more enthusiastic in class	4.00 (0.81)	4.00 (0.79)	3.66 (0.59)	4.50 (0.77)	ns
8. It can only be used by Year 10, 11 & 12 students	4.16 (0.91)	3.50 (0.67)	3.66 (0.89)	4.50 (0.93)	ns
9. It is too technical and unnecessary for my purpose as a teacher.	4.33 (0.67)	4.75 (0.88)	4.33 (0.69)	4.50 (0.93)	ns
10. Using the strategy can reduce the anxiety level of students in my subject	4.25 (0.82)	3.50 (0.69)	3.66 (0.82)	3.75 (0.82)	ns
11. I will find it difficult to teach my students the strategy	3.83 (0.79)	4.00 (0.69)	3.16 (0.81)	2.75 (0.77)	$p<.05$
12. Science/Mathematics is already complex; using this tool makes it more complex to teach.	4.33 (0.66)	4.50 (0.59)	4.00 (0.82)	4.25 (0.81)	ns
13. It is too abstract for me to learn.	4.56 (0.82)	4.75 (0.83)	4.16 (0.71)	4.25 (0.88)	ns
14. You need to be very intelligent to learn the strategy.	3.50 (0.78)	4.75 (0.66)	4.16 (0.82)	4.25 (0.82)	ns
15. Using it, will make my students demonstrate greater understanding of science	4.25 (0.98)	4.50 (0.92)	4.66 (0.87)	4.22 (0.97)	ns
16. I learnt the use of the strategy within an hour of being taught	3.50 (0.58)	4.00 (0.75)	3.66 (0.76)	2.00 (0.59)	$p<.05$

Note: S.D. values are in parentheses. ns = not significant.

A significant finding of the study is the slant brought into the concept mapping procedure by the teachers in the Australian sample. The idea of incorporating drawings, equations and worked examples in concept maps in chemistry, physics and mathematics would appear to have merit. This method of making concept maps will improve the integrative nature of concept maps. It will also serve to provide a richer linkage among concepts in a discipline. This slant to concept mapping is to be elaborated and tried out in a study that is soon to be under way.

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PRESERVICE SECONDARY SCIENCE TEACHERS MAKING SENSE OF CONSTRUCTIVISM

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ABSTRACT

This paper describes a naturalistic study of secondary pre-service science teachers and explores the process of implementing a constructivist approach to science teaching.

INTRODUCTION

Constructivist theory views the learner as one who actively "constructs" knowledge and meaning from their own experiences (Driver & Erickson, 1983; Driver & Oldham, 1986; Erickson, 1987). Research in this field (eg Driver, 1981) has been largely directed toward the study of children and is based on the premise that children's intuitive scientific concepts are learned from their everyday experience. However, some have argued that constructivist theory also applies to preservice teachers, not only in their understanding of science concepts but also their views of science teaching and learning (Hewson & Hewson, 1985; Aguirre, Gurney, Linder & Haggerty, 1989; Parsons, 1990).

Preservice teachers come with conceptions of teaching and learning. Often these are in conflict with the conceptions advanced in their teacher education program. Even when appropriate instruction is provided it may be difficult for preservice teachers to abandon their original views of teaching and learning. One process which has been described as useful in assisting preservice teachers to develop a constructivist approach to science teaching is reflection. By reflection I mean reflection-in-action and reflection-on-action (Schön 1983, 1987). MacKinnon (1988, 1989) in a study of preservice science teachers describes the role of reflection in constructivist science teaching.

THE PRESENT STUDY

The present investigation, by focusing on secondary preservice science teachers, explores the process of implementing a constructivist approach to science teaching. The study is a naturalistic one and evolved over the course of an academic year. The assumption of this type of research is that we can better understand what constructivist science teaching might look like by describing some aspects of the process that preservice teachers go through during their practicum. This paper will therefore focus on describing this process.

THE CASE STUDY

The sample consisted of ten students enrolled in a secondary science education program at a Canadian university in the Atlantic region. All held at least a bachelor of science and were required to complete a one year course in science education and a ten week practicum experience to fulfill the requirements for their bachelor of education. The investigator in this study acted as both their instructor and faculty adviser.

The science education course consisted of two parts. The first explored the nature and philosophy of science education, learning theories and instructional strategies during which the students were introduced to constructivism. The second half was primarily a methods course which focused on hands-on experience with the secondary science curriculum. During the first part of the course the students were introduced to the constructivist perspective.

The practicum experience was completed in three phases of four weeks, four weeks, and two weeks; with the latter six weeks taking place during the second semester. The faculty adviser in the practicum setting asked students to reflect on their teaching experience. The reflective process required the preservice teachers to analyze their classroom teaching. It was hoped that this reflection on pupils' understanding of classroom experiences and subject matter would result in the preservice teacher experimenting with new teaching strategies and activities for pupils.

The aim of the study was to describe the process that preservice teachers go through in implementating a constructivist approach to science teaching. The investigator's goal was to describe the process (analytical generalization) and not to enumerate frequencies (statistical generalization).

Multiple sources of evidence were used:

- a questionnaire (Aguirre et al., 1989) which surveyed preservice teachers' views of science, teaching, and learning was administered three times during the academic year (beginning, mid-point, and end).
- audio tapes of interviews with preservice teachers at the end of the final practicum;
- audio tapes of preservice teachers involved in large and small group instruction in practicum classroom settings;
- audio tapes of interviews with teacher advisers and representative students of preservice teachers; and
- field notes on classroom observations of preservice teachers during the three practicum experiences (a total of ten weeks).

Overview of Results

The preservice teachers' views of science, teaching and learning that were elicited on the questionnaire showed similar patterns to the U.B.C. data (Aguirre et al., 1989). The students entered the program with a view of science, teaching and learning; in most cases these views appeared to change in response to their science education program and practicum experience. Most preservice secondary science teachers enter the program with a transmissive view of science teaching. Initially, they resist change, but they then begin to test out constructivist teaching strategies after being exposed to their methods course. Coupled with this self-resistance, the pre-service teachers also referred to an institutional resistance to change.

The Resistance to Change

The first phase can be described as a resistance phase. All preservice teachers during my final interview commented that they initially had difficulty accepting a constructivist view of learning. Although I had worked with these students for eight months, I was not sensitive to the fact that they had problems initially accepting a constructivist view. It was in response to a comment made by the first preservice teacher I interviewed, at the end of the academic year, that I decided to ask all the preservice teachers about this resistance. It is important to note that the final interview took place after the final grading in the methods course and practicum had occurred. This suggests that the reported change in view on the questionnaire was largely due to performance for grades. Preservice teachers, like all university students have been conditioned to perform for grades and are therefore unlikely to openly display resistance. Such resistance was nevertheless present and the following discussion with one preservice teacher (whom I shall call Judy) is illustrative of preservice teachers' resistance to a constructivist view of learning.

I: Why are you now interested in what the kids think?

J: . . . . Especially when I stop and think about myself going into a class I know I have certain ideas and unless I really see the difference I don't think my ideas really change that much. You have pointed that out to us and I really believe it. Kids really have certain ideas and unless I can show them the difference. It is like you are saying they might memorize it now and give it to me on a test. But three months from now, the digestive system, for example they are likely to give me the same thing as they gave me before we started. I think that is the main reason for my changes. I realize that now.

I: Other than my saying that you should pay attention to children's science what other basis do you have to make this change on?

J: O.K, I think a lot of it would come to from what we as a class have said to one another outside what you said. most of us agree what seems to be working is the stuff that comes from the kids' perspective, not from our own . . . .

Here Judy talks about the need to be convinced about a new view of knowledge. Her convincing did not appear to come from the instructor and the literature but rather from her own experiences with students and peers. Another preservice teacher also referred to peer discussions during my interview with her. As a group they had often engaged in discussions which at the beginning of the year were often intense. Such discussions even resulted in a few tears being shed because of the disagreements over views of teaching. Further illustration of resistance was shared by Judy in a written comment at the end of the course.

J: I will admit that in September I doubted this "children's science" and "constructivism" and failed to see how it would help make us better science teachers; now I see differently. . .

Judy's description of her resistance is typical of the preservice teachers' responses. One student teacher (Peter) during the final interview, however, did not admit to resisting a constructivist view.

I: When you were first introduced to a constructivist approach to science teaching did you resist this approach?

P: No, I don't think so.

I: You didn't go through any period of rejection or anything like that?

P: Let me think you are talking way back in September, right?

I: Yes.

P: Eh, no I don't think so cause I didn't have any idealist views of the way things were anyway.

Based on such conversation Peter appears to have been more open to a new view of teaching. The classroom data collected on Peter's science teaching however did not reveal that he had made much progress at implementing constructivist teaching strategies. Nevertheless, such data might suggest that there may be some student teachers who may not go through a period of resistance, but they are rare.

As indicated previously, I was not aware that the students were resisting the constructivist perspective. I can recall no specific dialogue during class discussions that would have made me more sensitive to the fact that most of the students were having difficulty accepting a constructivist view. Given the "performance for grades" which occurs in most university courses it was very unlikely for a student to take such a risk. There was, however, much evidence from the practicum setting that the students were not implementing constructivist strategies in their teaching. When I discussed this with them during the post conference they would always say such things as, this is not the way that their teacher adviser taught, they were modelling after the teacher adviser, this is not the way science is taught in this school, or they have to cover the curriculum. In most cases they would always point out that things would be different in their own classroom. However the institutional resistance which the students referred to may not have been as strong however as the students led me to believe. Their reference to institutional resistance may have been one way of hiding their personal resistance to the constructivist view of the teaching/learning process.

One Preservice Teacher's Practicum Experience

Only one of the ten teachers in the sample (I will call her Gail), implemented a constructivist approach to science teaching in her classroom. This description is based on interviews with the preservice teacher, her teacher adviser, and four of her students. Gail. aged 23, was a science graduate with a major in biology and a minor in philosophy. Her teaching assignment for the practicum consisted of grades 10 and 12 biology. Her teacher adviser, Tom, was a 19 year veteran. He was well known and respected among his colleagues. He was actively involved in his own professional development both at the district and provincial levels. He did some inservice work in the area of environmental education and on one occasion during the school year did a workshop with all the students in the teacher education program. Based on informal conversations I had with some of his students he was often described as "the best teacher".

During my early conversations with Gail she emphasized that she wanted to be a good teacher. Her concept of how to become a good teacher was to model the best university professor that she had. She noted that she had many professors whose teaching was poor and that she didn't want to be like them. Her view of good teaching strategies was being able to do a good presentation: she saw teaching as dispensing knowledge. Her view was that how successful you were at teaching depended upon how well you could present the information to the students. Her metaphor for teaching at that time was teacher as entertainer (Tobin, 1990). Gail, like the other students in this study, went through a resistance phase. Her resistance is highlighted in the following conversation where she discusses her early view of scientific knowledge, and the change that had taken place in that view:

G: . . . . lots of information, lots of facts, I like knowing things in the simple way, the simple form of systems or situations so that. That was part of the reason

> why I was comfortable with the lecture method in September . . . . My whole idea of knowledge in biology was, eh having lots of information, lots of facts, and eh to be a teacher would be to pass on that information to the kids. . . . . There is still information, the information part of it is important I am not saying that it is not but it is only a basis by which the kids learn how to make their own inferences, to build their own connections, to create their own framework which they can see the world, not necessarily going to be the same as my framework. It is going to start with the same information but hopefully I will give them what is needed to make decisions as well as the freedom to make decisions. It is going to take a while because I have to do my own change around, a phase shift or something. What I was coming from before, my system before was very different, and trying to make room for thinking and trying to open up for broader ideas of what knowledge is all about is going to take some time.

At the end of her practicum Gail recognized that her view of scientific knowledge had moved from a positivist view of knowledge towards what she describes as a "broader view":

> G: I am growing towards a broader view, but I am still, I still have strong ties to the positivist tradition, yeah because that is what I have been working with for this last twenty years. So I have got to use that as a base now. I am not going to junk it all.

She restated that she had not abandoned her original view. What was significant in both responses was that she recognized that it takes time to change.

Shortly after the first practicum Gail visited me to convey her frustrations about the role of reflection during our post conferences. She did not see any point in reflection, she wanted to be told what she had to do and that I was to tell her what she was doing wrong. I tried to inform her of the role of reflection but I do not think I was successful at that time. The following conversation highlights some of Gail's earlier resistance. But what this seems to illustrate is that a preservice teacher has to be convinced of the benefits in order to change. At a later point in the conversation we explored whether she saw a relationship between change and reflection:

> G: . . . . Whole purpose of reflecting on your own work is to, or even to reflect on a situation is to come to some decision about it, hopefully in order to build on it. . . . . I would say that reflection is necessary for change if it is going to be healthy change and that reflection is meaningless if you are not prepared to change. There is no sense in criticizing your own work or considering other peoples' work, other peoples' strategies or attitudes if you are not prepared to accept a better one and change to a better one .

It appears that Gail felt that reflection should automatically result in change. Since a novice teacher has some special problems with reflection it was necessary to explore this further with Gail:

> G: For a novice, reflection is difficult I think because you don't know what to compare with, like you don't have your own experience to compare with . . . .

> I am still not part of the community yet. I am working at it but I don't pay attention to everything. I don't see everything because I still tend to be drawn into and focus too long on certain things. I can even get side tracked by things that might not even be important. I think that for me to have useful reflection on my own experience I have to. I have to draw on someone else's experience they have to point out what is important and what is not important because the things that I get very concerned about might not be important, as well the things that I pass off and don't give any credence to might be significant. The initial feedback is important especially in the first couple of weeks. I need somebody else to point out what is the norm in this little community . . . . It is like being an anthropologist, is it? In a new community and not knowing what the norms are . . . . You don't know what's important and what's insignificant. Everything is hitting you at once so it takes a while to pull those things out and you only want to focus on the important things.

Gail is not atypical of most novice teachers, I suspect, in that she initially found reflection difficult. This conversation emphasizes that preservice teachers have to acquire the norms of the teaching community before they are successful with reflection. The teacher and faculty advisers therefore play an instrumental role in helping preservice teachers acquire these norms before reflection can be meaningful to them. This also helps to explain Gail's frustrations with our attempts at reflection during the first practicum. As a faculty adviser who only met with her weekly I was certainly unable to provide her with the norms to the extent that her teacher adviser was able. Neither was I as sensitive as I should have been to the difficulties that a novice might be experiencing.

Gail's second practicum experience occurred about halfway through the teacher education program. Up to that point the preservice teachers had discussed constructivism, read numerous articles and explored constructivist teaching strategies. During this stage of the practicum experience Gail began to experiment with new teaching strategies and at that point she entered the experimentation phase. She was also relaxed enough to get a feel for her teacher adviser's approach to teaching. It was the final practicum experience, however, which demonstrated the most dramatic shift in her teaching strategies. Here Gail's creativity showed. She organized a stations approach to a study of marine biology. She encouraged the students, through group work, to make explicit their own understanding of marine fauna and flora and to explore further the biological descriptions for the specimens. She provided the students with a wide variety of printed and hands-on materials. I met with four of Gail's students at the end of the practicum. During this conversation the students described her teaching of the marine biology unit in the following manner:

S4: It was the way she taught it, instead of tell us how something is you are learning it yourself, like she, you glance impressions and you found out the answers. It was finer that way instead of having to sit there and watch her and write stuff down.

S1: She eh, she was kind of different like. She wasn't one who'd write all your lessons on the board and that she'd show you filmstrips or make it a little more interesting talking about her experiences.

S2: I think the way she did it. Keep you more interested.

S1: Trying

S2: Keep you from slipping out of class at the very end like copying notes from the board. You had to pay attention in her class.
S3: She use to pass out pictures and all that stuff for us to look at too.
S1: The labs, she helped us with the labs a lot.
S2: Yes.
S3: She was easy to eh, she had a lot of stuff available for everyone else in the class. She was easy to get along with in the lab.
S1: She didn't make you feel, feel stupid if you asked her a question. Look at you like, like you know.
I: How do you make a student feel stupid when they ask a question?
S1: They just give you a look. Give you a weird look or something, just, or say the answer sarcastically.
S2: She makes you feel comfortable.
S3: You are not nervous to ask her a question cause you know she is going to stand there beside you and lay it out for you the simplest way that she can.
I: Was she looking for the right answer?
S4: No, she was looking for your answer. She'd help you along.
I: Was she interested in what you were thinking?
S1: Yes, she was.
S2: She liked to have the class get their say in. She liked to hear what the class had to say. She'd give her view then she'd give the class an opportunity to give their view on what's going on in the class and what's she is teaching at the time.

This excerpt illustrates one of the basic tenets of constructivist teaching strategies in that her focus was on having students reveal their own ideas about a scientific concept. I explored this further:

I: Your own ideas: how much did she use that in her teaching?
S1: Well if you gave an answer she would say well let's look at that, that way and she would talk about it and if it was wrong then.
S4: She would show how it is wrong.
S1: And yeah, and then yeah, then she start on and if someone else had something to say she would just give the way it was suppose to be.
S2: She kind of felt that the opinion of the student was the most important part of the class because you are not really, really getting your point across, just standing there in front of a bunch blank eyes. Just talking away but making your students, getting the student involved. One or two students kind of brought everyone, everyone kind of jumped on, tried to get involved and made it more interesting, easier to pay attention. I think she covered that aspect she felt it was pretty important to have the students involved in every class.

The students were articulate about Gail's use of questioning as a teaching strategy for revealing student ideas about science concepts.

Gail's teacher adviser also had a dramatic influence on her teaching. During an interview at the end of the practicum Tom describes what he hoped Gail would learn about students:

T: . . . . What she is picking up from students is an appreciation for their differences. That each kid is totally different from somebody else. The last

> class she had everybody in that class works at their own pace, and everybody is just slightly different. Some kids have their idiosyncrasies and others do not and she is learning to handle that very nicely. . . . . She is very empathic towards them . . . .

Based on the above comment it is apparent that Tom's view of teaching is obviously student-centered. We explored how to achieve this.

T: At the beginning of the year it was a type of question and answer. Asking a question and then sometimes giving an answer. What has developed and I can see it now is. It has developed this way, asking a question and not giving necessarily the answer but allowing them to pursue their answers, as she did in the marine biology unit. . . . . let them reflect on it, think about it and try to assimilate a fairly decent answer. Whether it is right or wrong that doesn't matter. I think what Gail is doing that she has a long way to go, I don't think she has mastered it quite yet but I don't think any of us have.

When discussing the relationship between student teacher and teacher adviser Tom talked about passing on to the student more than just strategies for teaching but a love for teaching and that it is a worthwhile career. This allowed for an exploration of how this might be done:

T: I think if you enjoy teaching, if you enjoy anything, I think it is reflective. I mean it comes off as being. . . . . I have learnt from her and she has learnt from me. The kids have learnt from both of us and we have learnt from the kids. I have used strategies that she has used that I never even thought of, you know, and she has too.

His view of learning to teach is that it is a reflective process where both the adviser and the student share and analyze teaching experiences:

T: I want the student teacher to get an appreciation of what teaching is about. Let's face it, it is one of the most important professions there is. People disagree but I believe it is an important profession and as a result I think you are not coaching them, it is not a show and tell, you are not putting on acrobats, not acting anything out, you are doing what you feel is encouraging those kids to learn. . . . .

Tom obviously hoped that Gail would adopt a constructivist view. Since he had developed this view of teaching mainly based on his teaching experience then I would regard him as "a natural constructivist". There was no dialogue between the university adviser and the teacher adviser about constructivism. Tom's support of Gail was crucial to her development. The school's role was probably minor: since another four of preservice teachers in this study also worked in the same school, but they did not display the same shift towards a constructivist approach. They did not receive the same level of support for constructivist teaching from their teacher adviser.

When asked to provide a written critical review of constructivism Gail responded:

> .... the main criticisms of constructivism - that is too idealistic, unrealistic, and definitely more expensive (due to teaching aids, field trips, etc.) - are cop-outs....That it is more difficult is not adequate justification for not trying it... Education is a journey and whether you are a teacher or a student (and we are all students of a sort) you carry your own particular baggage when you begin. You pick up new things along the way, throw some things out and keep others. The destination is unknown and, I would argue, not reached in this lifetime.

Here Gail metaphorically describes the teaching-learning process as a journey. This metaphor presents a rich view of the teaching-learning process which can be described as constructivist. This is in strong contrast to her original transmissive view. Such a statement suggests that Gail may be moving from the experimentation phase to an adoption phase. Since this study did not go beyond the preservice level then exploration of the adoption phase would have to be undertaken in a follow up or longitudinal study. Given that Gail was the student who most successfully implemented a constructivist approach to science teaching then maybe some students such as Gail have a natural disposition or intellectual curiosity which makes them more receptive to change. Such students are likely to have self-confidence and be risk takers. These are two attributes that Gail appeared to possess. Beyond any natural disposition that Gail might have had she also had support at the school level from her teacher adviser. The other preservice teachers did not have the same level of personal and institutional support that she had.

DISCUSSION AND CONCLUSIONS

The results of this study can be summarized as follows:

- Most of the students, on the basis of the questionnaire, appeared to change their view of teaching. This change however was only on paper and was not demonstrated in most cases in the practicum setting.

- When asked to implement a constructivist approach to science teaching most of the student teachers went through a number of developmental phases. Two phases, the resistance and experimentation, were identified is this study. The first phase is one of resistance. The second phase is experimentation. It is also predicted that there may be an adoption phase. However further longitudinal studies are necessary to examine this.

- The personal disposition of the student together with advisory teacher and institutional support appear to be strong factors in influencing preservice teachers' acceptance of a constructivist approach.

Afterthoughts

The potential influence of the investigator on the outcome of the study must be acknowledged. The investigator in this case was both the instructor and faculty adviser for the ten subjects on which this study was based. Although an attempt was made to be open to the voices of the preservice teachers this might be better achieved by involving a co-researcher in such a study. It would also encourage more reflection on the approach taken in the course and during the practicum. Such reflections are necessary if researchers also wish to work from a constructivist perspective. Beyond the research approach being reflective there is a more fundamental question of the ethics involved in conceptual change. Future work in preservice education must be sensitive to the fact that preservice teachers beliefs about the teaching/learning process must be respected.

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THE CONSTRUCTION AND USE OF A METAPHOR FOR SCIENCE TEACHING

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ABSTRACT

While constructivism has emerged as a major reform in science education from the last decade, wide-spread adoption of constructivist practices in school laboratories and classrooms is yet to be achieved. If constructivist approaches are to be utilised more widely, teachers will need to accept a more active and constructivist role in their own pedagogical learning. One experienced junior science teacher was able to implement constructivist approaches in her classroom by using a personally constructed metaphor to guide her practice.

INTRODUCTION

Constructivism is an epistemology which focuses on the role of the learner in the personal construction of knowledge (von Glassersfeld, 1987). In the constructivist classroom, students are encouraged to take responsibility for their own learning as they make sense of experiences in terms of prior knowledge. Active teaching is required to monitor student understanding and help students restructure ideas (Driver, 1988). The more traditional transmission approach to teaching science contrasts sharply with constructivism. Knowledge is viewed as an entity which can be transmitted from the teacher's brain and deposited into the student's mind ("The Conduit Metaphor", Reddy, 1979).

Although science educators (Driver, 1988, 1989; Gunstone, 1990; Osborne & Freyberg, 1985; Pines & West, 1986; Tobin, 1990a) have mounted convincing arguments for greater use of constructivist teaching strategies, researchers (Tobin, 1990a; Tobin, Kahle & Fraser, 1990, Tobin & Fraser, 1987, 1990) have found that even exemplary science teachers have not embraced constructivism fully. Tobin (1990a) argued that previous reforms in science education, which called for a change in the teachers' role, failed because they neglected to take account of essential components of the change process in teacher education. These components were: personal reflection on epistemologies and beliefs, the construction of personal visions of classroom practice, and a commitment to personal change (Tobin, 1990a,). Perhaps the science educators who have attempted to persuade teachers to shift their beliefs and practices towards constructivism also have neglected to take account of these components of the change process.

Another possible problem with teacher education programs could be the failure of teacher educators to model appropriate constructivist practices for their students. Arguments for the wider use of constructivist approaches in teacher education programs have been expressed recently (Louden & Wallace, 1990; Marland, in press). Louden and Wallace, for example, proposed that science teacher educators should adopt an approach to teacher education which paralleled constructivists' views of learning school science. They argued that such an approach was not only more consistent epistemologically, but also more likely to assist teachers' pedagogical learning. The challenge for science teacher educators, then, is not only to design courses which build on teachers' existing beliefs and practices, but also to advance ways which might help these teachers improve their practice (Tobin & Fraser, 1990,).

The concepts of metaphor and image have emerged as powerful tools for investigating teachers' professional knowledge and thinking (Calderhead & Robson, 1991; Clandinin, 1986; Munby & Russell, 1990; Russell & Munby, 1989; Tobin, 1990b; Tobin et al, 1990). As a component of personal practical knowledge, an image is the coalescence of a person's personal private and professional experience. An image might form a mental dynamic picture or be expressed as a descriptive statement, sometimes metaphorically, and/or in practice (Clandinin, 1990,). In short, images can be visual or verbal (Weade & Ernst, 1990). Metaphors are related to images in that an image may be expressed verbally, in the form of a metaphor, and conversely, a metaphor might conjure up images of what it describes (Weade & Ernst, 1990). More specifically, Snow (1973, p. 82) defined a metaphor as "a compressed simile, usually a substitution of one kind of object or idea for another, to suggest a likeness or analogy between them".

Although recent studies (e.g. Tobin et al, 1990) of metaphors and images in teaching have suggested that metaphors influence science teacher thinking and practice, they have not investigated the deliberate application of metaphors by practitioners to guide their science teaching. In essence, until now, the question: "can metaphors be used to change teacher practice?" has gone unanswered. This question, therefore, was explored during and immediately following a Master's degree vacation school in science education at James Cook University where participating teachers were asked to construct personal metaphors for science teaching which might help them implement constructivist approaches in their own classrooms. This task was consistent with the approach advocated by Louden and Wallace (1990) in that participants were invited to assume an active and constructivist role in their own learning. This study focuses on how one participant, Bernice, constructed and used "the teacher as a travel agent" metaphor as a guide for her science teaching practice. Before describing the constructed metaphor and how Bernice used it to guide her science teaching, the concept of metaphor in science teaching is explored more fully.

METAPHORS IN SCIENCE TEACHING

Many recent studies of metaphors in teaching (e.g. Russell & Munby, 1989; Tobin, Note 1) were able to identify metaphors from the language used by teachers during lessons and as they described their pedagogies to researchers. These results seem to have supported the views advanced by Schon (1979) and Lackoff and Johnson (1980). Lackoff and Johnson, for example, argued that human thought processes are largely metaphorical. One of the first educators to realise the power of metaphors in developing theories of teaching, however, was Richard Snow who advocated using a heuristic, called "The Teacher as..." device (Snow, 1973). This metaphor generating device was responsible for such creative classical metaphors as "the teacher as a Bayesian sheepdog" and "the teacher as a whole earth catalog". By creating analogies between aspects of teaching and known things, concepts or roles in the form of metaphors, Snow argued that it was possible to elaborate ideas about teaching and play out the analogy's implications. Similarly, metaphors and images have been regarded as models for action (Calderhead & Robson, 1991) and self-fulfilling prophesies (Lackoff & Johnson, 1980).

Tobin (1990c) suggested that metaphors might be used as "master switches" to change belief sets and teaching practices. He reached this conclusion as a result of his studies of exemplary teachers in Western Australia (Tobin et al, 1990). The teacher identified as Peter, for example, conceptualised his teaching in terms of "captain of the ship" and "entertainer" metaphors. As Peter switched metaphors his teaching behaviour and interaction with students changed as well. Tobin suggested that if Peter could understand teaching in terms of the metaphor "teacher as gardener", he might adopt more of a nurturing role and might tend to the individual learning needs of his students. In this way, Tobin et al (1990, p. 236) asserted that: "the process of teacher change might be initiated by introducing a variety of metaphors and reflecting on the efficacy of basing teaching and learning strategies on each of them". Munby and Russell (1990) also recognised that the power of metaphor might be invoked profitably by teachers as a way of reflecting on and possibly improving their own practice. The most powerful application of metaphors in science teaching, however, might be found in the process where a teacher personally creates or constructs an image of his/her teaching and learning environments (Tobin, Note 1 & 2). In this study, Bernice made sense of constructivism through the process of creating and reflecting upon the metaphor of "the teacher as a travel agent". This metaphor is now described as it relates to Bernice's year ten science classroom context.

THE TEACHER AS A TRAVEL AGENT METAPHOR

Before taking the vacation school Bernice had admitted to being dissatisfied with her predominantly teacher-centred style of teaching even though she had, consciously and perhaps unconsciously, used various metaphorical roles (Note 3), like Peter, which were compatible with constructivist approaches. As an experienced science teacher working in comfortable conditions in a private girls' school, Bernice was nevertheless disappointed with not only her own performance, but also her students. Most of her year ten students found science difficult with little relevance to life outside school; they usually performed poorly on test items which required application of content to new situations. It was from this context that Bernice found the metaphor of the teacher as travel agent helpful in effecting a transition to constructivist practice.

For Bernice, the travel agent has an office seductively decorated with informative posters, brochures, reference books and souvenirs to entice the client to travel. The classroom can also provide seductive stimuli; those which might encourage a student to undertake a journey of exploration. The stimuli provide not only enticement, but also information. Films and videos for schools are analogous to the travelogues used by travel agents.

When clients enter the travel agent's office, the agent determines the clients' background (destination, purpose, previous travelling experience), needs (health, financial constraints), and preferences (individualised itinerary, guided tour, group booking, back-packer special). Similarly, the teacher can determine students' previous experience and knowledge base, as well as learning preferences (individual, group or whole class activities). If necessary, the teacher can advise students on time and resource limits, safety aspects, intellectual demand of tasks, and assessment instruments which need to be taken for particular topics.

By far the greatest resource available to a travel agent is him/herself. The agent has the information at his/her fingertips, or knows where and how it can be obtained. Usually the agent has already visited the places of interest and knows what clients "musn't miss". The teacher too, has a broad knowledge base and can suggest fundamental, as well as interesting steps in a topic. If required, the teacher/travel agent can act as a tour guide for any size group travelling to a destination, making appropriate stops/detours along the way.

In large group bookings, travel agents can expect a few of their clients to have visited certain locations on previous trips. The teacher, too, often finds that some students (e.g. transfers from other schools, own interests) have already explored a topic. A skilful travel agent/teacher can build on individuals' expertise by encouraging them to take on tour guide responsibilities or by suggesting interesting detours.

After a client has made a commitment the agent/teacher orders the tickets or makes the necessary bookings for the appropriate resources. The successful teacher-cum-travel agent can expect "postcards" on the progress of the trip, as well as the odd frantic phone call for assistance.

Unlike so many of the managerial metaphors such as policeman, entertainer, social director, executive, cited in the literature (e.g. Berliner, 1990; Tobin et al, 1990), the science teacher as a travel agent metaphor encompasses managerial roles as well as aspects of constructivist learning theory, thus eliminating the need for several metaphors from which to select or "switch" depending on the role requirement. The travel agent teacher encourages students to explore new routes as well as visiting well known destinations by establishing a supportive environment based on mutual respect and trust.

USING THE TRAVEL AGENT METAPHOR AS A GUIDE TO PRACTICE

At the conclusion of the vacation school Bernice made the commitment to try out the travel agent metaphor in her year ten science class. Although the conclusions, written in the form of tentative assertions, from this trial have been based on Bernice's personal accounts, collaborative evidence was obtained from students (interviews and informal comments) and several observers; including the science coordinator, other supportive subject teachers, and the teacher educator (Ritchie) with whom Bernice had worked on vacation.

ASSERTION 1: The use of the travel agent metaphor helped Bernice to change her lesson planning.

Before using the travel agent metaphor Bernice's lesson plans featured logical presentations of content with managerial annotations (e.g. apparatus list for the laboratory attendant). In addition, Bernice frequently prepared notes, from her content-rich lesson plans, which were copied and distributed to her students for revision purposes. Apart from a few unexpected incidents, the lessons typically were delivered as planned.

By becoming a "travel agent" teacher Bernice's lesson preparation was reduced and drastically changed.

> The physical aspects of preparing sheets of notes and experiments had been reduced drastically as now the students did that work, not me. In other ways I felt insecure as I could not plan too far ahead. I had to console myself with the fact that the travel agent could not plan each day a month in advance. My primary function now was to provide as many resources as possible to facilitate research, and to guide students to the most appropriate resources.

ASSERTION 2: By reflecting on the travel agent metaphor Bernice was able to maintain constructivist approaches throughout a biology topic.

The first topic scheduled for Bernice's class was The Human Body. In keeping with her image of the travel agent, Bernice used a brain-storming technique, at the start of each body system studied, to produce two lists on an overhead transparency: "what we know" and "what we would like to know". The students were invited to negotiate possible ways of finding answers to their questions. In the sub-topic of the skeletal system, for example, the class decided to work in small groups with x-rays, real bones, textbooks, skeletons from other animals, and audio-visual materials. As one observer noted, "although the students were moving around the lab a lot, they appeared to be on-task and were able to discuss with me what they had found out". After watching a video of one of these lessons, Bernice commented:

> ...I was amazed to see how active I was in the class. Except for a short introduction to the lesson where I was helping the kids to focus on the task, I was constantly on the move: directing students to sections where they could find books, setting up videos which some students had selected themselves, sending other students to the laboratory for other resources, and helping one group of students who had difficulties making sense of the reference material.

Interestingly, as Bernice noted, "when one student asked a question, another interrupted with 'don't ask Mrs Russell! she won't tell you, she'll just tell you where to look for the answer".

The students' efforts culminated in role-play activities where a representative from each group took on the persona of a guest expert who spoke on, and answered questions related to, the topic. Although the students widely accepted that they knew more about their topics from the detailed research required, they expressed reservations about how they would be assessed when compared with other year ten students at the school.

ASSERTION 3: Although assessment issues remain problematic, reflection on the travel agent metaphor has effected changes in assessment techniques and thinking.

In earlier studies of exemplary science teachers (e.g. Tobin & Fraser, 1987) assessment appeared to drive the curriculum. Not surprisingly, when Bernice's teaching style began to depart from patterns more familiar to her students, a number of reservations were expressed. During one class discussion, for example, Bernice fielded several questions which reflected students' insecurity in taking responsibility for their own learning. "What if we take too long to find the answers? We won't have time to do the other work we need for the test" and "Miss, you're teaching us the new way you learnt at this course aren't you? So, what if you get it wrong and we fail our tests and can't do next year's work?" were typical of the students' concerns.

It was obvious to Bernice that the assessment items selected for the topic test should reflect the change in emphasis in her teaching, previously described. Short answer items, to allow for wider acceptable responses, replaced multiple choice items. In addition, there was a greater emphasis on process questions than previously. To Bernice's disappointment, however, the students did not perform as well as she had expected. In a "post mortem" discussion, the students appeared to know more than their results suggested and most students complained that they needed more time to think through their answers while some students suggested that they had difficulty interpreting the questions. The most rewarding aspect of the discussion, for Bernice, was that the students were able to analyse their test performance and identify areas for improvement, for themselves.

Bernice turned to the travel agent metaphor to try to resolve her dissatisfaction with the test as an assessment tool. How does a travel agent know if the client has experienced everything on a trip? The agent can ask questions, but may not get the full picture without seeing the photos, postcards, travel diary, home movie, and letters. The question for Bernice became, was a test the best method for assessment? Would it not be better to examine the record of students processing information from various resources? The skills and techniques for monitoring student progress and profiling have yet to be developed and tested.

Assessment of student progress is problematic in terms of the travel agent metaphor and constructivism. Travel agents don't set out to assess how well their clients follow their negotiated itineraries, but rather how well the itineraries satisfy their clients' needs. The demand from society, for teachers to assess their students, conflicts with constructivism thus limiting the application of the travel agent image to classroom life.

ASSERTION 4: Bernice was able to resolve many classroom problems by reflecting on the travel agent metaphor.

The travel agent metaphor was helpful in resolving some assessment concerns as well as other classroom problems which presented on occasions. For example, at one stage Bernice was concerned at the quality of student questions; they seemed to have asked questions for the sake of asking questions. As Bernice disclosed:

> I reverted to the travel agent image and realised that, for anyone planning a trip, it is impossible to say what you want to see until you know all that there is to see, plus you need to clear up any misconceptions. To this end, at the beginning of the excretion topic, I revised digestion, using the model torso, to show that defecation was part of digestion, not excretion. I also showed a video (travelogue) which gave an overview of the whole topic. ...There was an improvement in the range and quality of the student questions for this topic.

DISCUSSION

Even though not all of Bernice's students greeted the constructivist approaches with enthusiasm, all agreed that changes had occurred. The change process began when Bernice decided that she wanted some sort of change before enrolling in the science education vacation school. After studying constructivism and personalising her understanding of what constructivist practices would be like in her own class, by creating the travel agent metaphor, she committed herself to trying-out her new approaches. By reflecting on the travel agent metaphor she was able to plan and implement lessons which were consistent with constructivist epistemology. As problems arose, Bernice turned to her image as travel agent. On each occasion she was able to resolve the issue without reverting to more traditional methods. Bernice's experience not only reinforces the literature on the change process (Tobin, Note 2), but also highlights the potential that the processes of creating and reflecting on personally constructed metaphors might have for improving classroom teaching.

Bernice's success in transforming her teacher-centred approach to constructivism, by reflecting on the travel agent metaphor, suggests several lines of inquiry. Firstly, it would be worthwhile to determine if experienced and beginning teachers alike can experience similar success in embracing constructivism by reflecting on the travel agent metaphor or if the real power lies in the process of creating personal metaphors and images. Secondly, there is a need in pre-service teacher education to plan, implement and evaluate constructivist programs which integrate students' preconceptions and beliefs about teaching with conventional pedagogical content (Marland, in press), perhaps by using the metaphor construction process described here. Finally, as Bernice approached her colleagues for support during the trial period, the travel agent metaphor became a tool of communication between teachers when discussing pedagogy. Therefore, there might be some value in investigating the effects of shared construction and reflection on metaphors, like the travel agent, for staff professional development.

While Bernice experienced success during a biology topic where resources were widely available, can application of the travel agent metaphor yield similar results when teaching "out of field" (e.g. physics) or where resources are scarce? In addition, is the metaphor sufficiently resilient and flexible to sustain long-term use and use in settings which are less conducive to teacher risk-taking? These questions deserve consideration. Perhaps the assertions identified in this paper can be used to guide further studies in the use of constructed metaphors of science teaching.

In an atmosphere where the use of metaphors in teacher education programs gains momentum, the important issue of the validity of a metaphor for educational practice needs to be considered. Some metaphors might conjure up inappropriate images of classroom practice in the minds of student teachers, especially when individuals do not participate in the construction process. The criteria for assessing the validity of the teacher as a travel agent metaphor, in Bernice's case, were derived from constructivism. Perhaps all metaphors, constructed or proposed for application in science classes, should be validated using similar or other appropriate criteria.

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Note 2. K. Tobin. Initiating and sustaining change in the science curriculum. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, GA, April, 1990.

Note 3. Prior to commencing the vacation school participants were asked to complete a questionnaire which required them to identify significant teaching roles. Bernice listed the following roles: coordinator, resource manager, lecturer, trouble-shooter, disciplinarian, entertainer, leader, supervisor, facilitator, and listener.

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PRIMARY SCIENCE AND TECHNOLOGY: HOW CONFIDENT ARE TEACHERS?

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ABSTRACT

Science and Technology is a new Key Learning Area in NSW Primary Schools. Survey results are used to compare preservice teachers (on entry and in the third year of their degree) with practising teachers, on their confidence in their knowledge about the topics in the syllabus, as well as their confidence to teach these topics. Reasons for stated confidence (or lack of it) are reported together with preservice and practising teachers' views about what needs to be done to improve their confidence. Preservice and practising teachers' opinions of the major sources of their knowledge about the topics in the new syllabus are contrasted. Results are discussed in the light of several Discipline Review recommendations.

INTRODUCTION

The NSW Department of School Education has recently disseminated (July, 1991) the new Science and Technology [S&T](K-6) syllabus to schools. There are several similarities between this syllabus and the English science curriculum (DES, 1989b) in that specific knowledge and understanding learning outcomes are defined for three levels (compare with attainment targets for various stages in the English document). Concern was expressed on the English scene about the adequacy of primary teachers' science knowledge in relation to the attainment targets (DES, 1989a). A similar concern was also reported by the Discipline Review of Teacher Education in Mathematics and Science [hereafter referred to as the Discipline Review] (DEET, 1989) about preservice teachers' (PSTs) confidence levels (relating to whether they felt they had sufficient knowledge and experience for teaching particular science studies at K-3 and 4-6 year levels). This study further explores the confidence levels of preservice and post-initial education teachers (PIETs). It attempts to answer the following questions: (1) What are PSTs' and PIETs' confidence levels about their knowledge of the topic areas in the new NSW syllabus? (2) What do PSTs andPIETs believe to be their main source of knowledge on the topic areas? (3) How are confidence levels about knowledge of topic areas related to confidence levels to teach those topics? Are both these confidence levels related to actual time spent teaching the topics? (4) What reasons do PSTs and PIETs give for their confidence and lack of confidence about particular topics?

PROCEDURE

A questionnaire was devised to determine PSTs' and PIETs' confidence levels ['little or none'; 'some'; 'a fair amount'; 'a lot'] about their knowledge of the nine topic areas (6 content strands and 3 processes) in the new NSW Primary Science and Technology (K-6) syllabus. The topic area headings (e.g.: 'Living Things'; 'The Design and Make

Process' etc.) were each accompanied by a synopsis of the area derived from the syllabus. The teachers were also asked to indicate, from a range of options, what they believed to be their main source of knowledge for each topic area (the underlined words were highlighted in the questionnaire). The options were post-secondary science and/or technology (S/T) studies (non-curriculum courses); upper secondary level S/T; lower secondary level S/T; preservice S/T curriculum studies; post diploma/degree curriculum studies, e.g.: graduate diploma course; professional development courses/activities; teaching children S/T ('during the practicum' was added for preservice teachers); hobbies; other (please specify). Confidence levels to teach the particular topic areas (across K-3 and 4-6 year ranges) were also sought and for PIETs their recollection of how much ('little or none' etc.) they taught children in their classes in the last year in each of the content strands was ascertained. All teachers were asked, via open ended questions, to give reasons for their lack of confidence in particular topic areas and what they thought would increase their confidence. For those topic areas in which they already had 'a fair amount' or 'a lot' of confidence they were asked to give their reason(s) for their confidence. Background information about the teachers was collected.

The questionnaires were administered at the commencement of the 1991 academic year to first year students in the Bachelor of Teaching degree [Group A], students at the commencement of semester 5 (who have completed their compulsory science and technology curriculum studies units in their Bachelor of Education [Stage I] degree)[Group B]; and Bachelor of Education [Stage III] students [Group C] who are resident in NSW. The sample sizes for each group were: commencing students (n= 126; response rate, 100%); semester 5 students (n = 52; response rate, 56%); Bachelor of Education (Stage III) students (n = 40, response rate, 22%).

Some general characteristics of the three groups of teachers are as follows. The preservice and post-initial teacher samples are predominantly female (Group A:79%; B:88%; C:68%), having completed at least one S/T subject at year 12 (or equivalent) (A:78%; B:75%; C:75%). Most PSTs have studied biology for matriculation (A:38%; B:39%; C:13%) but a significant minority of practising teachers have completed only school certificate level science (23%). Of the PIETs, 80% have taught within the last year, at the following year levels: K-3 (15 teachers); 4-6 (10 teachers); K-6 (7 teachers). The mean years teaching experience is 11.9 (S.D. = 8.6) with only 4 teachers having no teaching experience. The years since completing their initial training varies considerably (mean 14.0; S.D. 9.4; range 0 to 31).

RESULTS AND DISCUSSION

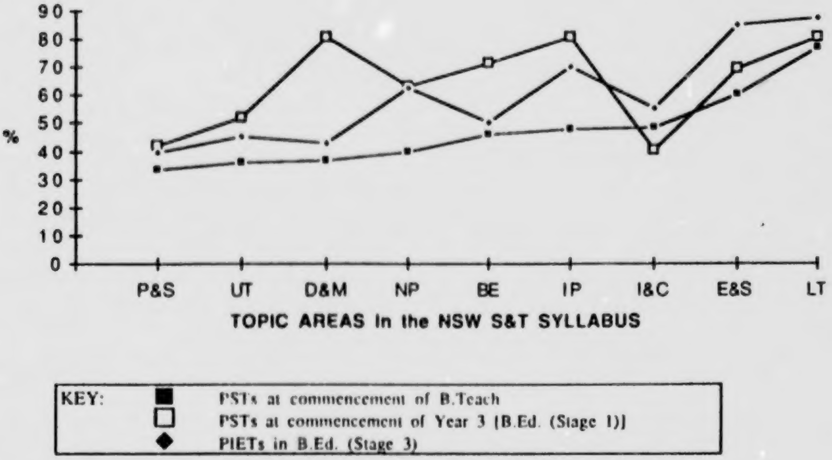
Confidence about Science and Technology Knowledge

The NSW Science and Technology (K-6) syllabus has six content strands and emphasises three processes. A summary of teachers' confidence levels about their knowledge of the nine areas is shown in Fig. 1 (More complete data are presented in the original conference paper, available from the author.) The data indicate that:

* third year PSTs and PIETs are more confident than commencing PSTs about their knowledge on all topic areas except 'information and communications.' For BE, NP, IP, D&M and UT topic areas (see Fig. 1 for abbreviations) the difference between first and third year students is significant at the 0.05 level

and for E&S and IP topic areas PIETs are significantly more confident than commencing students ($p < 0.05$).

- although third year PSTs are more confident than PIETs about their knowledge on all topics except I&C, E&S, and LT, the difference is only significant ($p < 0.05$) for the built environments topic area and the design and make process.



	TOPIC AREA	CONFIDENCE LEVELS about KNOWLEDGE of TOPIC AREAS					
		Entry PSTs		Semester 5 PSTs		PIETs	
		Percentage Confident	(Mean)*	Percentage Confident	(Mean)	Percentage Confident	(Mean)
1	INFORMATION & COMMUNICATION (I&C)	48.4	(2.44)	40.4	(2.33)	55.0	(2.63)
2	BUILT ENVIRONMENTS (BE)	46.2	(2.41)	71.2	(2.90)	50.0	(2.40)
3	LIVING THINGS (LT)	77.0	(3.03)	80.4	(3.14)	87.5	(3.25)
4	PRODUCTS & SERVICES (P&S)	33.4	(2.21)	42.3	(2.39)	40.0	(2.25)
5	NATURAL PHENOMENA (NP)	39.7	(2.33)	63.4	(2.81)	62.5	(2.60)
6	THE EARTH & ITS SURROUNDINGS (E&S)	60.4	(2.75)	69.2	(2.89)	85.0	(3.13)
7	THE INVESTIGATING PROCESS (IP)	47.7	(2.40)	80.8	(3.10)	70.0	(2.83)
8	THE DESIGN & MAKE PROCESS (D&M)	36.6	(2.27)	80.8	(3.10)	42.5	(2.43)
9	THE USING TECHNOLOGY PROCESS (UT)	35.7	(2.21)	52.0	(2.60)	45.0	(2.43)

* Percentage confident is the number of teachers with 'a fair amount' or 'a lot' of confidence about their knowledge of the topic area.
Mean is the mean confidence level where 1 = little or none; 2 = some; 3 = a fair amount; 4 = a lot.

Fig. 1 Percentage of teachers with 'a fair amount' or 'a lot' of confidence about their knowledge of the topic areas.

- Less than 50% of all three groups of teachers are confident about their knowledge of 'products and services' and 'the using technology process'. The majority of commencing PSTs and PIETs also lack confidence about their knowledge of 'the design and make process', whereas commencing and third year teachers lack confidence about the 'information and communications' topic area.
- more than 50% of all three groups are confident about their knowledge of the 'earth and its surroundings' and 'living things' whereas the majority of third year PSTs and PIETs are confident about 'natural phenomena' and the 'investigating' process.

Of the content strands and processes in the NSW Science and Technology (K-6) syllabus five areas are 'new' compared to the previous Investigating : Science (K-6) curriculum policy statement (NSW Department of Education 1980). These are the I&C, BE, P&S, D&M and UT. For teachers who completed their preservice training an average of 14.0 years ago, and who have been involved in very few professional development activities related to science and/or technology in the last ten years [14 teachers had not been to any in-service courses, 5 to one and 6 to two in that period; 3 had been involved in extensive professional development in this area], it is not unexpected that they would feel less confident about these new content strands and processes. [The higher confidence rating for I&C may be partially explained by practising teachers' perceptions of this topic area as being similar to a common social studies theme, and that many teachers now use computers in their classrooms.]

Of further interest is that PIETs are less confident about their knowledge on these new content strands than the more physical science strands (natural phenomena and the earth and its surroundings) which are acknowledged to be less regularly taught than the biological sciences (Symington & Rosier, 1990) and have been reported (Yates & Goodrum, 1990) to be areas of lower confidence among practising teachers. That this is also the case for commencing PSTs suggests that the task for preservice and post-initial education of teachers is to some extent similar.

The confidence levels of semester 5 B.Ed. students is somewhat unique to the current study in that these sample of students have completed science curriculum units from a particular preservice program. The results however warrant consideration. These students had completed one 12 week science and technology unit (60 contact hours with equal time being given to science and technology) focusing on the new syllabus. The 'investigating' and 'design and make' processes permeated all aspects of four themes: 'Built environments' (2 weeks); space (component of 'the Earth and its surroundings' - 2 weeks); energy and forces ('Natural Phenomena' - 5 weeks); and 'Information and Communications' (1 week). Students were also required to teach a 3 to 6 S&T lesson sequence (emphasising the investigating and design and make processes) during their three week block practicum and submit a report on same. Science-technology-society interactions, emphasising aspects of the 'Using Technology' process (in total about 2 weeks) and specific curriculum/pedagogical issues completed the unit. The results suggest that if professional development opportunities become available practising teachers' confidence about their knowledge of these topic areas could also increase.

Analysis of the confidence levels of the three groups depending upon the gender, mode of entry into preservice teacher education and the science and technology background of the teachers indicated that:

- There were no significant differences ($p < 0.05$) between males and females on entry except that males are more confident (2.67) than females (2.23) about the Natural Phenomena topic area. This difference is not apparent with semester 5 PSTs or PIETs.
- Mode of entry had no significant effect upon the confidence levels of commencing or semester 5 PSTs.
- The S&T background of commencing PSTs suggests that those who had studied one HSC S/T subject (mostly biology) were more confident about 'Living Things' (3.23) than students who completed year 11 S/T (2.62) or SC science and/or technology (2.47). This group of entry PSTs were also more confident than SC entrants about the 'Earth and its Surroundings' (as are students who studied two HSC S/T subjects or post-secondary S/T). Students who had completed two HSC S/T subjects (usually including a physical science) were more confident (3.04) than all other groups about 'Natural Phenomena'. These differences were not apparent with semester 5 PSTs or PIETs

Sources of Science and Technology Knowledge

Figures 2A and 2B display what teachers believe to be their main source of knowledge for the various topic areas:

- Lower and upper secondary level science and/or technology courses are cited by an average 28% and 56% respectively of all commencing PSTs as their main knowledge source about the syllabus content strands. No other single source was nominated by more than 10% of the commencing PSTs.
- The influence of secondary school science and/or technology studies as the main knowledge source declines considerably after two years at University, and except for topics 'Living Things', 'Natural Phenomena' and 'The Earth and its Surroundings' this decline continues after teachers leave university.
- For semester 5 PSTs and PIETs the contribution of upper secondary level studies is seen by less than 10% of the groups as a main knowledge source for all the 'new' content strands (I&C; BE; P&S) and processes (D&M; UT) except for P&S by the semester 5 PSTs (group B).
- As PSTs progress through their degree program two new sources of knowledge tend to compete with and partially displace secondary level studies: university preservice S&T units (being cited by between 9% [P&S] and 53% [IP] of PSTs at semester 5 level, depending upon the content strand); teaching children science and technology during their practicum (being cited by 5 [P&S] to 37% [D&M]).
- PIETs tend to continue the above mentioned trend with teaching children being nominated for all topic areas by between 25% and 34% of teachers. The influence of preservice programs (for PIETs) varies considerably for different content strands being nominated by less than 10% for I&C and BE; between 10% and 20% for P&S, NP, and E&S; and by more than 20% for all other topic areas with a high of 25% for IP.
- Professional development (PD) activities have made a small contribution to all topic areas with between 5% and 14% of PIETs nominating this knowledge source.

Figure 2A Teachers' perceived knowledge sources for topic areas in the NSW S&T syllabus
(Percentage of teachers citing each source)

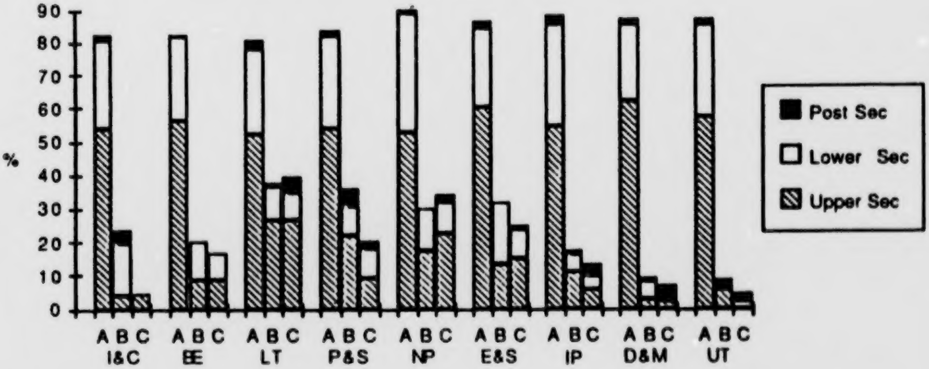
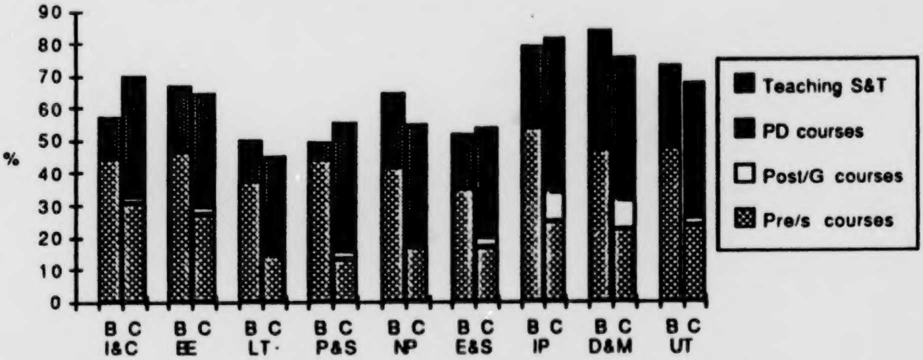


Figure 2B Teachers perceived knowledge sources for topic areas in the NSW S&T syllabus
(Percentage of teachers citing each source)



KEY: SAMPLES
A = PSTs on entry to B.Teach program
B = PSTs at commencement Year 3 (B.Ed.)
C = Post-initial education teachers (B.Ed. [Stage3])

TOPIC AREAS:
I&C = Information & Communications
BE = Built Environments
LT = Living Things
P&S = Products & Services
NP = Natural Phenomena
E&S = The Earth & its Surroundings
IP = The Investigating Process
DM = The Design & Make Process
UT = The Using Technology Process

- Post diploma/degree level studies are nominated by few teachers (9%), and then mainly for the processes of investigating and designing/making.

Not shown in Figures 2A and 2B is that 'hobbies' and 'other' activities/courses are the main knowledge sources nominated by between 4% and 28% of teachers depending upon the topic and the group of teachers. Typical examples of 'other' sources of knowledge and the topic areas they relate to are: employment experiences (I&C; P&S); involvement in the conservation movement (E&S; UT); work as a builder's labourer (BE); completion of a fitness course (LT); and learning with one's own children (IP).
These data suggest that concentrated upper secondary studies (e.g. years 11 and 12 biology) tend to have a lasting effect on particular topic areas (e.g. LT). Natural Phenomena also seems to fall into this category. For other topic areas different sources of knowledge either 'fill the gap' or tend to replace secondary studies as the main source. The Discipline Review recommended that "primary teacher education should expect that all students have at least a year of study of ... broadly based science in years 11 and 12" (DEET, 1989, Vol.1, p.38). How broadly based can the year 11 and 12 science studies be in order for teachers to retain them as a main source of knowledge, one question arising from the above data. The NSW S&T syllabus does include five topic areas that have a technology bias and current HSC science subjects do not focus on most of these topics. There would appear to be a limit on what can be expected of secondary science studies with such a wide range of content strands in the syllabus. Of course other HSC subjects can be of value, e.g. Technics, Geography, Computing Science, and Engineering Science, and these were listed by a small number of teachers (e.g. 8% of entering PSTs) as sources of HSC knowledge.

The possible impact of preservice S&T units is also relatively clear. Provided adequate attention is given to the syllabus topic areas in the preservice units about 40% of year 3 PSTs nominate such units as a main source of knowledge for the content strands. Some PIETs continue to cite their preservice training as a main knowledge source, but 'teaching children' seems to assume greater importance for practising teachers. This effect starts to appear in preservice teacher education and is support for the Discipline Review's recommendation that teacher education programs ensure "that there is a close relationship between curriculum studies/methodology and the practicum" (DEET, 1989, Vol.1, p.xxvi; 42-44). The process 'design and make' dramatically illustrates this effect, where 38% of semester 5 PSTs cite teaching children as their knowledge source for this process [the practicum assignment referred to earlier is believed to be mainly responsible (the vast majority of PSTs reported on using this process in their practicum reports)].

Professional development (PD) and post-diploma/degree courses have had little impact, yet PD (in-service) activities are the most quoted means (by PIETs) of increasing confidence in the topic areas (see below). Considering the small involvement in PD (S&T) by teachers in the current sample the result is not surprising. Similarly as only about 5% of the current B.Ed. (Stage III) enrolment have completed the Stage III S&T elective unit the number citing such a source of knowledge is not unexpected. It could be inferred though that when PIETs have done a post-degree/diploma unit in the S&T area then that often becomes a main source of knowledge. The current B.Ed. (Stage III) units emphasise IP (and to a lesser extent D&M) and this seems borne out in the data.

Reasons for Confidence/Lack of Confidence

Both PSTs and PIETs said that they were more confident about their knowledge of particular topic areas because they had more knowledge of that area with between 25% (semester 5 PSTs) and 59% (commencing PSTs) of responses giving this reason. A mean of 22% (across topic areas) of all commencing PSTs specifically stated their confidence was due to year 11/12 studies, with up to 38% indicating this for the 'Living Things' topic. This further supports the contribution year 11/12 studies make towards PSTs' confidence, and for LT and E&S the effect remains for PIETs. HSC studies are not a strong contributor for some topic areas (e.g. BE, D&M, P&S).

The complete data indicate that three other reasons for confidence were included in 20% percent or more of the responses by one or more groups: interest in the area; used in practicum/taught a lot; and preservice courses. Again the role of teaching a topic area to children as a source of confidence about the area is reinforced, as well as the part played by preservice units. A range of other reasons was given by a small number of responses, and it is interesting to note that professional development courses are absent from the list given by PIETs. Of the reasons given for lack of confidence 'lack of knowledge/unfamiliarity with content' is the most cited, and as expected is the most common response to how to increase confidence with 63% of all PIETs stating 'in-service' courses would fulfil this requirement. Other reasons for lack of confidence (included in more than 10% percent of responses) were: lack of interest in the topic area; lack of resources; and deficiencies in preservice courses. Two of these are paralleled in the suggestions for ways to increase confidence (access to resources and 'better'/different teaching of the areas [at school/university]). The complete data however, show once again that PSTs (well into their program) believe experience with children is the way to improve their confidence about the topic areas in which they lack confidence [32% of the sample specifically stating this remedy]. Among the other reasons and suggestions for improvement given, two minor aspects warrant mention: some entering PSTs specifically refer to their negative attitudes towards computers (mainly mature age entrants) and PIETs (23% in this sample) perceive that other teachers (and on fewer stated occasions, consultants) can be important in improving their confidence.

Confidence to Teach the Topic Areas

The questionnaire assumes that the respondents are able to distinguish between their confidence about their knowledge of a topic area and their confidence to teach that topic area. With this qualification in mind the following results are reported. It would appear that teachers may feel more confident to teach a topic than they are about their confidence of their knowledge of the topic. An example of this trend is that with, for 6 of the 9 topic areas, 10% or more practising teachers say they are more confident to teach K-3 the topic areas, than those who say they are confident of their knowledge of the topic area. This trend is accentuated with entering PSTs where it occurs for 8 of the 9 topics. The confidence to teach year levels 4-6 is more closely correlated with confidence about knowledge of the topic areas [in all instances the correlation coefficient is lower for confidence levels between knowledge and teaching K-3, than for teaching 4-6]. If this is a valid interpretation it is interesting to note that semester 5 PSTs do not show such obvious differences; also for PIETs (and perhaps for semester 5 PSTs) this trend to be more confident to teach K-3 appears to relate to the topic areas about which they are least confident in their knowledge (PIETs: I&C, BE, P&S, NP, D&M, and UT; PSTs [semester 5] : I&C; P&S and NP). Another way of expressing this possible relationship is that confidence to teach K-3 seems to be more independent of teachers' confidence about their knowledge of a topic area than confidence to teach 4-6; however as teachers grow in confidence about their knowledge of a topic this difference decreases. The statistical basis for this relationship needs further exploration.

Amount of Teaching of the Topic Areas

For practising teachers (n = 32) there is a fairly close agreement between the rankings for the mean 'amount of teaching' (of the topic area in the last year) and the mean 'confidences about knowledge of the topic areas.' Similar agreement in rankings is found between confidence to teach K-3 and 4-6 and the amount of teaching. These data would suggest that confidence measures are a reasonable indicator of the relative amounts of time teachers actually spend teaching particular topics in the classroom.

If the data are representative of the population of practising teachers (rather than teachers upgrading their qualifications to degree level), then four topics in the new syllabus are taught 'a fair amount' or 'a lot' by more than 50% of teachers (LT, 87.5%; E&S, 75%; NP, 65.6%; and IP 56.3%). None of the 'new' topic areas fall into this classification, despite 50% or more teachers being reasonably confident about their knowledge of some of the topics (BE, I&C), or their confidence to teach the topics (K-3/4-6:I&C, BE, K-3 only P&S; D&M).

CONCLUSIONS

This study indicates that the 'new' topic areas need to be specifically addressed in preservice and professional development courses as entering PSTs and PIETs are least confident about these areas. When these areas are addressed then the results for semester 5 PSTs indicate that the confidence levels rise. [It should be noted that apart from I&C (mean confidence rating 2.33), P&S (2.39) and UT (2.60) all semester 5 PSTs ratings were above 2.80 which the Discipline Review considered satisfactory (DEET, 1989, Vol.2, p.36).] As previously stated the 'new' areas in the S&T syllabus could all be considered to have a technology bias, and although the Discipline Review commented that graduate PST confidence about most science topic areas was "poor or marginal" (p.36), this study suggests the 'new science and technology' areas included in the syllabus are rated lower than the traditional science topic areas. This has obvious implications for preservice and professional development courses: it is made more challenging as NSW has decided that technology will be linked with science at the K-6 level. Compare this with the Discipline Review's summary which stated that technology education is creating for itself a place in the school curriculum "in its own right", and added that several European countries have moved in that direction (DEET, 1989, Vol.3, p.159).

The sources of knowledge which PSTs and PIETs associate with their confidence levels change over time with upper secondary studies being most influential on commencement of preservice education (and remaining influential for some topics when PSTs graduate). Preservice courses then become an important source of knowledge but soon start to share that contribution with "learning" by teaching S&T to children. This last mentioned finding is reinforced by the responses to the 'open questions' given by the teachers, in which many semester 5 PSTs (and PIETs) said their confidence about their knowledge of S&T topic areas was due to teaching those topics. This supports linking curriculum studies courses (pre- and post- diploma) to practice teaching assignments, and professional development courses to trial and reflecting upon actual teaching in relation to topic areas. Internship programs would appear to be supported by this study; entering PSTs are enrolled in such a programme.

Considering the importance that the Discipline Review placed on science discipline knowledge these findings about main knowledge sources for content topics require further investigation. If 'teaching children S&T' is perceived as a key source of knowledge then should more time be devoted to this aspect at the expense of the already limited time available for formal preservice university-centred course studies? Also further exploration of the data may reveal some knowledge sources lead to greater confidence such as was found for (biology) HSC studies and 'Living Things'. That commencing PSTs and PIETs appear to believe that teaching K-3 requires less confidence in knowledge about the topic areas also poses interesting questions. For example, how much knowledge about forces and movement does a K-3 teacher need to help young children clarify their ideas? If Kruger & Summers' (1989) data relating to English primary teachers' misconceptions about physical phenomena apply in the Australian context then perhaps the apparent extra confidence for K-3 teaching is misplaced.

Several other issues could be raised by these data. Our intention is to further explore the research questions by following the commencing cohort of students through their preservice program in order to ascertain the effects of their internship program and to obtain a larger sample of B.Ed. (Stage III) teachers in future years to try to determine whether practising teachers' confidence levels improve as the new curriculum is in NSW schools for longer periods.

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ISSUES OF TEACHING SCIENCE TO NURSES IN THE TERTIARY SECTOR

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ABSTRACT

The shift of nurse education from the hospitals to higher education institutions has resulted in a large pool of students within the Universities requiring basic science instruction. Most of these students are female, often mature age, with limited science backgrounds. This paper discusses the type of science education demanded by the nursing profession, the view of science as a subject held by these students, and the key role played by constructivist thinking in dealing with both of these.

THE SCIENCE CURRICULUM CONTEXT

By 1994, the transition of nurse education from teaching hospitals to the higher education sector will be virtually complete. In South Australia alone, this will mean a supply of approximately 1000 nursing graduates per year. From 1992, the basic nursing award in most schools of nursing in South Australia will be a six semester Bachelor of Nursing (BN), replacing the six semester Diploma. In the majority of cases, the BN consists of discrete, basic units in three main areas; nursing theory and practice, the psychological and social sciences, and the biophysical sciences. In courses where these areas are not fully integrated, nursing theory and practice units engage between 65 - 75% of the course time. This means the psychosocial science and the bioscience units each engage about 12 - 18% of course time.

Student contact with science is limited to one unit per semester, and often less, out of an average of four. In that space of time, students are expected to gain a working proficiency in health-related aspects of the following: basic anatomy and physiology, pathophysiology, pharmacology, microbiology, genetics, chemistry and physics. The science program at one school of nursing in South Australia is summarised in Table 1.

In addition to difficulties arising from the extensive content suggested by such a range of topics, there are two additional problems. Firstly, the unit material should be presented with a clear nursing focus; that is, it should be seen as allied with nursing practice. This sets selection criteria for what is to be the content taught in genetics, for example, but ignores traditional notions of developmental learning in science; there is no time for progressive conceptual development. This is closely linked to difficulties with depth of coverage. For example, can nursing students come to a reasonable understanding of metabolic reactions without knowing atomic valances? Judging from the standard textbooks in this area, the science educators assume students cannot.

TABLE 1.
SCIENCE IN THE NURSING PROGRAM

Semester	Topics	Weeks	Hrs/wk
1 and 2	Anatomy & Physiology, Introductory chemistry Introductory physics	20	10
3	Pathophysiology/Pharmacology	10	8
4	Microbiology	10	5
5	Genetics, radiation, environmental health	10	5

Note: the 5 hours per week are divided into 2 one hour lectures for up to 250 students, and 1 three hour practical/tutorial with about 25 students per group.

The second problem is that of integration. The science content and methodology should be integrated by both the teaching teams and by the students. When the nursing staff are teaching about clinical asepsis, frequent reference should be made to material taught by the science staff dealing with microbiology; specifically, control of infection, and disease processes associated with pathogenic organisms. This allows little time for the consolidation of underlying science concepts and information. And, as integration is a higher order cognitive skill, in the sense of being able to synthesise material, the students are expected to function at this high level with little preliminary study.

THE STUDENT CONTEXT

The situation described above may not be a major concern if the students were carefully selected for a strong science background, but this is not the case. Several Australian studies of the entry characteristics of nursing students (Bishop 1990; Kershaw, 1990) show that a typical nursing student is female, either fresh from school or returning to study after an absence of over eight years. In the latter case, her educational history often contains little or no science and/or mathematics beyond year 8. Some students have been Enrolled Nurses (EN; two years hospital training) for many years, who have perceived themselves to be operating successfully without any science, and who have observed many Registered Nurses (RN; three years hospital or tertiary training) doing so as well. Some students feel anxious about their ability to deal successfully with tertiary study, particularly those units that require quantitative skills. In short, they are under-prepared for science study, highly anxious, and often harbour long-standing negative feelings about science.

One possible source of this hostility has been described (Lumb & Strube, 1991). The traditional views of nursing and nurses that have become part of the stereotype of nursing over the years were examined. These images were then contrasted with the stereotypical view of both science and scientists. In brief, these contrasts can be summed up in Table 2.

TABLE 2
KEY WORDS FROM LITERATURE SURVEYED

Scientists/Science	Nurses/Nursing	
masculine	feminine	subservient
lab coat	mother-like	deferential
eye glasses	cuddly	peripatetic
facial hair	routine clinicians	ministering angel
researcher	token torturers	handmaiden
knowledgeable	doctor's assistants	battle axe
technologically competent	patient	whore
intelligent	kind	
dependable	brave	
valuable	angels of mercy	
hard working	girl fridays	
cold	heroines	
icy robot	wives	
emotionally inhibited	positive	
boring	active	
unsociable	lacking knowledge	
unimaginative	subordinate	
conservative	glamorous	
narrow-minded	mysterious	
male chauvinist	simplistic	

One implication drawn from that study (Lumb & Strube, 1991) is that many women who choose nursing as a career find it difficult to imagine themselves doing science, or even talking or thinking science.

CONSTRUCTIVIST APPROACHES

Gunstone (1990) presented a timely and cogent account of 'children's science' and constructivist views. What was said there seems powerfully borne out by recent experience with nursing students. If the table of key words truthfully reflects views of nursing and science, then science teaching and learning with these students should begin by dealing with attitude conflict. Until now, efforts in this direction have been limited to encouragement and role modelling; pointing to successful nurse clinicians and educators and saying, in effect, if they could do it, so can you.

The remedies, are neither obvious nor impossible; much valuable work has already been done. Particularly pertinent here is the idea that it is "the learner who is responsible for recognising their existing ideas/beliefs, evaluating these, and deciding whether or not to reconstruct these existing personal constructs" (Gunstone, 1990, p.16). The ideas and beliefs that need exploring with these students extend beyond science concepts to their image of what a scientist is and does. We are now firmly in the business of attitude change, not only conceptual change.

In nurse education there is a recognition of the difficulties in adopting constructivist methods (such as those outlined by Gunstone) given the time constraints with large numbers of students, but these are challenges which we are starting to feel competent to face. What is not at all clear are the appropriate strategies to use for these students in re-evaluating attitudes towards science. In the eyes of many of these students, nursing is about care, and science is not; nursing is a feminine, nurturing activity while science is seen as masculine and analytic.

Two approaches being considered for handling this problem are outlined here The first is the use of short science summer schools; the second is adoption of a problem-based learning approach throughout the curriculum.

For two years, 1990 and 1991, the science staff have conducted week-long summer schools for beginning nursing students. The program consisted of 12.5 hours of lectures to upwards of 120 students. Providing this cohort with some fundamental scientific and mathematical background information was one primary aim. Another important aim was to provide a science learning experience which was positive, open-ended, and affirming. To this end, the lecturers were careful to emphasise the interest and relevance of their subject to nursing as a career. Nurses were shown to be active users of scientific information; key communicators of scientific information to their clients; and partners in the process of scientific research in health care settings. All of this was intended to start the students imagining themselves actively and positively engaged in science.

The success of this approach has not been properly evaluated. The design of an appropriate evaluation tool for attitude change is one of the projects for the science team in 1991/2. Since not all of the first year entry students participated in the voluntary summer school, there is a self-selected control group for comparisons if desired.

The second approach, problem-based teaching and learning methods (PBL), has not yet been fully implemented. Some units within the nursing studies component of the course have begun to adopt PBL. It demands a complete integration of all three components; nursing studies, the psychological and social sciences, and the biophysical sciences. The University of Western Sydney has adopted full PBL within its nursing school; informal communications suggest considerable success in terms of the preparation of nurses. What is not clear is whether such an approach can deal with the two central problems identified by this paper: adopting constructivist methods that engender meaningful learning within the constraints outlined above, and the negative views of science held by nursing students.

The core of a PBL unit is a case study, e.g., the treatment of a patient admitted to hospital suffering from insulin coma. The student assesses the problem, and seeks the information and skills needed to deal with all aspects; scientific, communicative, and nursing. Because the scientific knowledge is seen to be on a "need to know" basis, it is claimed, at least by those who use it, to be highly relevant and necessary, and therefore readily learned. This claim is not supported by any data. Nor is it strongly supported by similar work with PBL approaches in school science. There, teachers became confused over exactly where the emphasis should lie; with the skills of problem solving, or with the concepts to be taught and learned using this approach. That is, was PBL content or method or both? It appears that nurse education using PBL is caught up in the same concerns. Nurses should be good problem solvers, but there is also a great deal of information and skill to acquire before competency is recognised by registration as a RN.

However, even if there were strong evidence for the success of PBL in learning nursing skills, there remains the question of its effectiveness in bringing about the attitude change argued for earlier. It may be true that by competently doing science on a "need to know" basis, the nursing students come to realise that they can, in reality, successfully do science. Their negative attitudes would slowly disappear, replaced by feelings of confidence and interest.

Again, there is no evidence for this yet. The possibility remains that these students still end up feeling that the science they needed to know to solve the problems embedded in their case study is alien, generated by anonymous authorities with skills far beyond their own, and extremely difficult. A real danger is that, not having gone through a deliberate process of re-evaluating their beliefs and ideas, they simplistically apply textbook knowledge without either conviction or understanding. As currently understood, a PBL approach is not predicated upon making the learner's current understandings part of the problem to be investigated. As a result, students may continue to think of science as a necessary evil to be overcome in their quest for licensing as a registered nurse.

RECOMMENDATIONS

Three recommendations can be made. They are generally curriculum issues, requiring no major restructuring of resources, but they have implications for time allocation, and possibly of staff commitments. The first is to incorporate full PBL methods within schools of nursing through constructivist approaches. Note the assumption already made that PBL is a method, not part of the content. This will be vigorously debated by nurse academics who see problem-solving as a critical characteristic of the nurse. If this proves to be a dominating viewpoint, comprehensively incorporated into the PBL curricula, then the point still remains that, to use Gunstone's terminology again, **recognising, evaluating** and **reconstructing** previous knowledge should still be major features of the program. This has significant implications for the time allocation to science within PBL. Clearly, rather than a reliance on textbook answers and information, the student must take responsibility for spending time, probably with guidance, undertaking meaningful conceptual change. As well, this may constitute a hiatus in the PBL program, unacceptable to the expected pace and integration.

The second recommendation addresses the problem of convincing nursing students that such an effort is worthwhile. The curriculum should identify the role of **metacognition** in teaching/learning. Here, the emphasis is not just on reflecting on one's own thinking, but on one's own views of what type of knowledge should be valued, and how that knowledge is generated and personally constructed. This means the curriculum must deal with issues of value clarification, constructivist models and philosophies.

Thirdly, work must be done to deal with learning problems that may be associated with the contrasting images of science and nursing held by these students. Several things come to mind. This issue could be dealt with within the PBL curricula itself, by specialists in sociological factors involving stereotyping. However, the current emphasis with PBL is with the sociological context of nursing within a multicultural Australia, as it effects the interactions of nurses with their clients. That is, the emphasis is on the altitudes of nurses towards their clients, rather than towards aspects of their own learning. Significant changes to curriculum emphasis would need to be made.

It may, however, be best to deal with this issue through the use of carefully structured science summer schools or bridging courses. Within a longer time frame, activities dealing with attitude change could take place within a context of learning some basic science. The use of constructivist methods could more easily take place in such a setting, free from other time constraints. Such a summer school would need to be longer, with different objectives, with contributions from staff with different expertise, such as attitude change. Attitude change and stereotyping are issues that have been addressed by educators within sociology for many years, and their help would be essential.

CONCLUSION

Tertiary science for nurses operates with large numbers of students, short contact times, and negative attitudes from students. Constructivist methods, in so far as they deal with student re-assessment not only of knowledge but of attitudes, are well-placed to help this situation. Problem based leaning strategies can also assist, if they contain a firm grounding in constructivist thinking. Science summer schools, deliberately aimed at attitude change, also suggest themselves as part of the remedy.

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SCIENCE DISCIPLINE KNOWLEDGE IN PRIMARY TEACHER EDUCATION: RESPONSES TO THE DISCIPLINE REVIEW OF TEACHER EDUCATION IN MATHEMATICS AND SCIENCE

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ABSTRACT

This paper describes a study of primary teacher educators reaction to those aspects of the Discipline Review of Teacher Education in Mathematics and Science dealing with early childhood and primary pre-service teacher education. Interviews with two of the authors of the Review are also reported.

INTRODUCTION

There has been growing interest in the discipline knowledge of primary teachers and how this impacts on their classroom performance (Symington & Hayes, 1989; Brophy, 1991). In the Report of the Discipline Review of Teacher Education in Mathematics and Science (Speedy et al., 1989) the authors suggest how tertiary institutions might address the issue of improving the science discipline competence of primary teachers. Amongst others, they recommend that concurrent programs should

- have a minimum of 72 hours of face-to-face contact (excluding examinations);one of the units in which these hours occur to be preferably in first year, but not later than semester 1, year 2;
- have the equivalent of one unit of science discipline knowledge (including physical science) which is explicit and assessed;
- use diagnostic tests with the availability of catch-up units (optional units to which some students are directed);
- provide electives in science education.

The authors set out to gain insight into the response of teacher educators to some of the recommendations and suggestions made in the Report of the Discipline Review. This paper draws on the data gathered which is relevant to the debate about the discipline knowledge of students in primary teacher education programs.

METHOD

There were a number of stages in the research. The first involved the development of an instrument through analysis of the Review Report. This was administered and the results followed up with interviews of some respondents. In the final stage the responses of key members of the Review to the data gathered were sought through use of the questionnaire and interview.

The research began with a detailed analysis of that section of Volume 1 of the Report which deals with early childhood and primary pre-service teacher education (pp. 37-44). This revealed 61 separate suggestions. An instrument was developed to provide data on responses to each of these suggestions, most of which were included without change as items in the instrument (in some cases minor changes of wording were necessary to create statements appropriate for instrument items).

The instrument comprised two sections. In the first, respondents were asked to indicate (using a 5 point Likert scale, from highly inappropriate to highly appropriate) their view of how appropriate each of the 61 statements was for teacher education in Victoria. In the second they were asked to indicate (using a 5 point Likert scale, from no priority to very high priority) their view on the priority that Victorian institutions responsible for teacher education should place on these same statements. The final section asked the respondents to select the five statements to which they would allocate the highest priority.

All staff responsible for teaching the science education components of primary teacher education programs in Victorian higher education institutions (33 people) were asked to respond to the instrument. Nineteen replies (one of which was claimed to represent the views of 2 people) were received and analysed. After analysis, three respondents were interviewed; the selection of people for interview was based entirely on availability at a particular time. Those interviewed were asked to explain their responses to those suggestions which they saw as inappropriate, or about which they were unsure. They were also asked to explain the reasoning behind their choice of the five statements they gave the highest priority.

The final stage was to gather data on the views of two key members of the Review, Dr Speedy and Professor Fensham. They were asked to complete sections 2 and 3 of the questionnaire, and were then interviewed. The interview focussed on those items for which their response was significantly different from the views of a number of the teacher educators who had responded to the questionnaire.

TABLE 1
NUMBERS OF ITEMS IN VARIOUS CATEGORIES
REPRESENTING RESPONDENTS' VIEWS OF THEIR APPROPRIATENESS.

Category	How defined	Number of items
A. Universally and strongly supported.	All rate as HA or A. More than 3/4 rate as HA.	6
B. Universally supported.	All rate as HA or A. Less than 3/4 rate as HA.	14
C. Widely and strongly supported.	More than 90% rate as HA or A.	13
D. Supported by majority.	More than 60% but less than 90% rate as HA or A.	23
E. Significant lack of support.	Less than 60% rate as HA or A.	5

Key : HA = Highly appropriate.
A = Appropriate.

ANALYSIS OF THE QUESTIONNAIRE DATA

The first section of the questionnaire asked the respondents to indicate their views on the appropriateness of the suggestions in the Report of the Review. Table 1 presents an analysis designed to give an overall impression of the level of agreement between the respondents and the authors of the Report. This analysis shows that whilst some of the suggestions made in the Report have widespread and strong support, there are others for which there is a significant divergence of opinion (Category E).

TABLE 2
ITEMS FROM THE QUESTIONNAIRE FOR WHICH THERE IS A SIGNIFICANT LACK OF SUPPORT

Item	Number of respondent				
	HI	I	UN	A	HA
2. The program should include a diagnostic test that can serve to affirm the knowledge these students already have and identify gaps that can be remedied by suitable bridging studies.	1	4	3	7	4
5. If science curriculum units are to provide some of the science learning beyond the level at which it is pitched for primary learners, it is important that this distinction is very explicit.	0	3	8	6	2
13. The equivalent of 50 percent of the 72 hours should be devoted to specific science content in both physical and biological topics. 1	4	3	7	4	
14. The specific science content needs to be explicit and assessed, with students expected to achieve a minimum level of competence.	2	3	3	7	4
58. Until the appropriate strategies of science teaching and learning have been developed on their own, student teachers should not be expected to ensure their effective presence at the same time as they are trying to emphasise number, language, social and aesthetic learning.	1	7	3	6	1

Key : HI = Highly inappropriate
I = Inappropriate
UN = Unsure whether appropriate or not
A = Appropriate
HA = Highly appropriate

Table 2 presents the data for items in category E, that is those for which there was a significant lack of support. It should be noted that four of the five items (2, 5, 13 and 14) appeared in that part of the Report labelled Science Studies and are concerned with the science discipline aspect of the courses as distinct from Education and Curriculum Studies and the Practicum.

This analysis suggests that it is in the area of Science Studies that the greatest divergence of opinion occurs. A further analysis of the data, as presented in Table 3, supports this view.

TABLE 3

CATEGORIZATION OF RESPONSES TO ITEMS IN THE VARIOUS AREAS COVERED BY THE QUESTIONNAIRE

Category	No. of items referring to:			
	Science	Edn.	Curric.	Prac.
A. Universally and strongly supported.	3	0	1	2
B. Universally supported.	0	3	9	2
C. Widely and strongly supported.	2	1	6	4
D. Supported by majority.	8	2	7	6
E. Significant lack of support.	4	0	0	1
Total	17	6	23	15

Key :
Science = Science Studies
Edn. = Education Studies
Curric. - Curriculum Studies
Prac. = Practicum

In the second section of the questionnaire the respondents were asked to indicate, for each item, the priority that Victorian institutions should place on the suggestion. Table 4 presents an analysis of the data designed to show the relative priority given to the suggestions in the various areas, that is Science Studies, Education Studies, Curriculum Studies and Practicum. It will be noted that relatively few people gave high priority to suggestions related to Science Studies.

TABLE 4
DISTRIBUTION OF ITEMS ACCORDING TO PRIORITY ACROSS THE STUDY AREAS COVERED BY THE QUESTIONNAIRE.

Category	No. of items referring to :				Total
	Science	Edn.	Curric.	Prac.	
X. Rated by more than half respondents as High priority.	4	1	7	6	18
Y. Rated by less than half but more than a quarter of respondents as High priority.	4	5	13	4	26
Z. Rated by less than a quarter of respondents as High priority.	9	0	3	5	17

Key :
Science = Science Studies
Edn. = Education Studies
Curric. = Curriculum Studies
Prac. = Practicum

In the third section of the questionnaire the respondents were asked to select the five suggestions to which they would give the highest priority. There was little agreement between people here. Of the 61 items 44 were chosen by at least one person to be amongst the five to be given the highest priority.

THE INTERVIEW DATA

The interviews highlighted the divergence of views and revealed some of the reasons for people's reaction to the Discipline Review suggestions. For the purpose of this paper the focus of the interview data will be on the divergence of views about Science Studies. It would be misleading however to focus only on the lack of agreement. There was very strong support for the inclusion of studies designed to improve the science knowledge and skills of primary teacher education students. The first item on the questionnaire was "The program should include studies in science knowledge and skills that are appropriate to the content of primary science and which will build the confidence of the students in the field." This statement was rated by all respondents as appropriate or highly appropriate, and as high priority or very high priority by all but one. Further it was the statement most frequently chosen amongst the five to be given highest priority (chosen by 6 respondents). It was not the notion of advocating Science Studies per se which generated dissent. Rather it was the associated ideas, such as the use of tests and the specification of time to be allotted to such studies, which revealed divisions amongst the teacher educators.

Diagnostic testing

As was indicated earlier, the Review Report recommended that a diagnostic test be utilised to ascertain the science knowledge of students entering primary teacher education courses. One of the Review panel strongly supported the recommendation on the grounds that it is one way to "guarantee that people will take knowledge seriously".

One of the respondents, whilst acknowledging the significance given to knowledge when testing occurs, was less certain about this recommendation.

> Whenever I see something like diagnostic test that concerns me because the test itself tends to drive the programme...That's why I wasn't sure. I didn'tknow exactly what was meant by a diagnostic test. I would want to see some illustration of the sort of test we're talking about before I said 'Yea' or 'Nay'."

Not only did the authors of the Report propose that the courses for primary teacher education students should dedicate a minimum amount of time to the treatment of science discipline content, they also proposed that the specific science content should be "explicit and assessed,with students expected to achieve a minimal level of competence". (p.39) This statement was one of the 5 chosen as highest priority by one of the Review panel interviewed.

Such a level of support for this proposal was not shared by many of the teacher educators who responded to the questionnaire. Only one chose it amongst the five to receive the highest priority. Further there were seven who thought that the proposal should receive only moderate, low or no priority.

Time allocation

Another of the suggestions in the Report of the Review, that 50% of the time allocated to science should be devoted to specific science content, was seen as inappropriate by a number of the teacher educators. One of those who held this view argued:

> I'm not sure why we should focus on these particular percentages, assuming that somehow, given a certain amount of time, we're going to bring about a particular outcome. We have to make sure that we've got the attitudes, the feelings, on side first of all. Then we might be able to do some research work and see, yes, O.K., we're able to bring about a definitive change in behaviour given 50% or 40%. To me this is just a figure plucked out of the air. I'd like to see some justification for that sort of value. But first we have to work on the attitude side of things.
>
> To me this implies that by clocking up the hours you're going to bring about behavioural change to the way science is taught. I'm not convinced that is so. I believe you could spend 100% of the time working on specific science content and still find teachers not wanting to teach science. But if they feel science is really important they change their values. You might find that you only have to spend 10% of the hours and they want to find out more for themselves. That'll affect behavioural change and that's what we want. That's why I've got reservations about that being so explicitly spelt out.

This view was not shared by all of the teacher educators. For example, one argued that the time devoted to Science Studies should be more than 50%.

DISCUSSION

In the study data were collected from a relatively small number of people. The size of the sample is not a cause of concern from a research point of view since the reality is that the number of people actually involved in the education of primary teachers in science is relatively small. What is important is that the research has established that there are some recommendations of the Discipline Review which do not find favour with all of this group.

In this paper the focus has been on the issue of Science Studies. The Review Recommendations appear to have been based on the belief that one of the keys to the improved competence of primary teachers in teaching science is to ensure that adequate attention is given to Science Studies in primary teacher education programmes. Whilst not disputing the place of science discipline knowledge in teacher education courses, some teacher educators appear to be unconvinced that the suggestions regarding testing and time allocation to such studies are the appropriate ways to approach the issue.

It would seem that there is more to be done in opening up the matter for further consideration. Perhaps the issue to be addressed is not how much time should be devoted to Science Studies but how teacher education can improve the understanding of science by primary teacher education students and how those understandings can be assessed.

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A COMPARISON OF AUTHOR INTENTIONS AND STUDENT PERCEPTIONS ABOUT TEXTBOOK CHARACTERISTICS

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ABSTRACT

The textbook is often accepted as a fundamental resource in a science classroom because the assumption is made that students are able to interpret a text in a manner which is congruent with the author's intentions. For example, where an author seeks to promote student cognition through the inclusion of specific elements, or implies a high degree of social awareness through the incorporation of societal characteristics in a text, it is expected that students will, at least, perceive these emphases. This research questions these assumptions and suggests that if textbook authors wish to communicate such ideas to students, then they should do so in an overt manner.

INTRODUCTION

Very little has been written about Australian junior science textbooks and student perceptions of them. There are many more American studies of this kind. This study focuses on two junior science textbooks used in Queensland schools.

Most high school science students have access to a science textbook. In most cases their teachers choose which textbook is used in the classroom and, according to Holliday (1984), 'reading is one of the most frequently used instructional strategies reported by practicing (American) science teachers.' Although there seems to be no research on the subject, anecdotal evidence would suggest that a similar observation could be made about Australian science teachers. There is, however, evidence to suggest that gaining understanding from reading a science textbook is far from an easy task. Scruggs (1988), for instance, reports that 'a science textbook can introduce as many as 2 500 new technical terms. A foreign language course requires half that number'. Textbooks typically support a 'transmission teaching' model and few have been designed specifically to help students modify their own understanding of scientific ideas or even modify their attitude to science and scientific endeavours. This results in negative outcomes for science teaching. As Harder (1989) puts it, 'many students become frustrated when reading their science textbooks and rationalise this frustration by saying they do not like science'.

American research has revealed enough information to produce guide-lines for the writing of science textbooks. For example, Anderson and Armbruster (1984) suggest that authors need to pay attention to structure, coherence, unity and audience appropriateness; Holliday (1984) lists features which good science textbooks should contain and Holliday (1986) provides specific directions for authors by stating a number of rules for designing textbooks. While textbook writing might be considered an activity of a global nature, there is no guarantee that all features applicable to the structure of textbooks for American students will necessarily apply in Australia for Australian students.

These guide-lines represent current notions of good textbook design. Authors of science texts are aware that good communication is the essence of their craft. They are aware that the way they use language and the way they combine it with photographs and illustrations is critical. The guide-lines also recognise at least some of the assumptions associated with a constructivist model of learning. For instance both Anderson and Holliday indicate that concepts in the text should be related to the prior knowledge of students. With this current discourse about textbook design one might hope, then, that textbooks today would be more 'user-friendly' than in the past.

Both teachers and students are users of science textbooks, but Morris (1989) believes that it is mainly teachers who read and learn from textbooks. He feels that they then explain to the students what is in the book. Students, on the other hand, according to Roth & Anderson (1988), only use textbooks because 'most teachers ask their students to read textbooks and expect them to learn from their reading'. Unfortunately, according to Roth & Anderson, students don't necessarily understand what they read.

For students to gain the benefit from a textbook they must be able to use it efficiently. Ideally students should gain from the textbook what the author intended. In other words, the transmitted information and ideas (in the textbook) become received information and ideas for the student. There is a myriad of factors that mitigate against such ideal transfer, including students' attitudes to the use of the text and their perceptions of text materials. Relatively little information is available about students' attitudes towards science textbooks (Harder, 1989). Even less is known about the way students perceive science textbooks. One might posit that, if students are to gain benefit from text features they must, at the very least, perceive the existence of such features in a textbook.

The authors of this study have set out to compare the intentions of textbook authors with the perceptions of students about the textbooks they use. In particular the study seeks to determine whether there are significant differences between student perceptions of textbook features and the emphases authors reported they placed on these features when writing their books.

METHOD

The Instrument

Data collection was by the use of two questionnaires developed primarily from the text characteristics used by Spiegel and Wright (1984), Merzyn (1987) and Holliday (1986). The characteristics obtained from these sources were augmented by the researchers in direct response to current social concerns about multiculturalism and gender and equity in order to produce a comprehensive list of text book characteristics.

Thirty-four characteristics were identified and used to prepare two separate, but congruent questionnaires. The student questionnaire was trialled for clarity of directions and revisions made accordingly. Since the form of the student and author questionnaires was the same it was not considered necessary to trial the author questionnaire.

In the first questionnaire, textbook authors were asked to indicate the level of importance of each characteristic 'when they were writing their Junior Science Textbook'. A five point scale was defined so that authors could indicate the level to which each characteristic influenced the manner in which the text was written. Each scale was explained in detail on the questionnaire. For example:

> 'Very important' indicated that the author believed that a characteristic was fundamental to the manner in which the text was developed and was used consistently throughout the text.
>
> 'Fairly important' indicated that the author agreed strongly with the feature but that there were times when she/he chose not to use it.
>
> 'Of moderate importance' indicated that the author used the features sometimes but did not feel compelled to use it any more than she/he did.
>
> 'Of little importance' indicated that, while this feature may have been incorporated somewhere in the text, it occurred more by chance than design.
>
> 'Of no importance' indicated that the author did not think about it or ever consciously used it in the text.

The second questionnaire, given to students, asked them to reflect upon the textbook they had used and to show how much they thought each item had been used in their current textbook. They were asked to choose one of the following. The meaning of each term was included in the questionnaire and is reproduced below.

> 'Used all the time' indicates that you believe that this feature has definitely affected the manner in which the text was produced because it is used whenever possible throughout the text.
>
> 'Used most of the time' indicates that you believe that this feature has affected the manner in which the text was produced because there is evidence of it throughout the text, but there are a few times when it has not been used.
>
> 'Sometimes used' indicates that you believe that this feature appears to have had some influence on the manner in which the text was produced because there is occasional evidence of it.
>
> 'Seldom used' indicates that you believe that there is little evidence of this feature in the text. At most there may be one or two indications of it in the text.
>
> 'Never used' indicates that you believe there is no evidence that this feature has appeared in or has influenced the manner in which the text was produced in any way.

The text was available to students as they answered the questionnaire so that they could refresh their memories if necessary. The intention was not to determine the extent to which these features actually appeared in the textbook, but rather to determine the extent to which students perceived these features to occur in the textbook.

The textbooks and students in the study.

Two books were arbitrarily chosen for the study. The first (Book 1) was a book from a well established series widely used throughout Queensland. The second (Book 2) was a book from a new series that places emphasis on process rather than on content. Its authors indicate that it is designed to offer students the opportunity to observe, question and experiment with their world. The authors of each textbook agreed to complete the author questionnaire.

After a pilot study was conducted in two Brisbane state high schools, one for each book, the student questionnaire was administered to 292 students in thirteen Year 9/10 classes from six state and two private schools in Brisbane. The schools were selected based on their use of one of the two textbooks chosen for this study.

Categorisation of questionnaire characteristics.

To facilitate the treatment of data, the thirty four characteristics used in the questionnaires were classified into categories. This was done using the 'expert opinion' of ten tertiary personnel, who were asked to work independently to place each characteristic in one of three possible categories - features associated with structural characteristics of a textbook, features which reflect social concerns, and features which are related to cognition. The items were then allocated to these categories based on the opinions of the 'experts'. In the four cases where 70% agreement was not achieved using this technique, the items were discussed by the combined panel of the same experts and allocated by consensus to an appropriate category.

DATA AND DATA TREATMENT

The data collected from the questionnaires were collated and tabulated. See Table 1.

The Kruskal-Wallis Test (Linton & Gallo, 1975) and White's (1952) small sample adaptation of the Wilcoxon Test were used to determine the significance of the differences between author's intended use of textbook features and students' perception of the existence of those features in the textbook. Results of these tests are shown in Table 2.

DISCUSSION

One of the reasons for carrying out this study was that a pilot study conducted within two Brisbane schools, indicated that students and authors perceived the existence of social features in a textbook very differently from each other while not significantly varying in their opinions about structural or cognitive features. It was hoped that this larger study would substantiate these findings. However, the results, as shown in Table 2, clearly indicate that significant differences exist with respect to all textbook features used in this study.

Provided the assumption can be made that students who have used a textbook for two or three years, as was the case in this study, are reliable judges of just what features the textbook contains, then the only conclusion that can be drawn from these results is that the authors of these two texts have not made their intentions sufficiently explicit for students to recognise.

TABLE 1
AUTHOR AND STUDENT RESPONSES TO QUESTIONNAIRE ITEMS

Item	Feature Category	Book 1 Author Response	Student Response (Mean)	Book 2 Author Response	Student Response (Mean)
2	A	5	4.16	5	4.25
14	A	4	3.01	5	3.20
17	A	5	3.63	1	1.68
24	A	5	4.11	5	4.27
28	A	5	4.29	5	4.50
29	A	5	3.51	5	2.37
36	A	5	3.84	5	3.98
37	A	5	4.11	5	4.25
4	B	4	2.96	5	3.58
5	B	4	3.09	5	3.90
8	B	5	2.73	5	2.84
15	B	3	2.48	5	3.06
16	B	4	3.12	5	3.40
19	B	2	1.77	5	2.25
1	C	5	3.72	5	4.40
6	C	2	3.40	2	3.53
7	C	3	3.20	5	3.60
9	C	4	3.12	5	3.37
10	C	3	2.93	5	2.65
11	C	5	4.17	5	4.51
12	C	4	3.96	5	4.11
13	C	5	4.08	4	4.51
18	C	4	3.27	5	2.65
22	C	4	2.63	5	2.70
23	C	5	3.78	4	3.46
25	C	5	4.08	4	4.12
26	C	5	4.32	5	4.07
30	C	5	4.56	5	3.57
31	C	5	4.34	5	4.29
32	C	4	2.75	5	2.58
33	C	3	2.49	5	2.15
35	C	3	2.40	2	2.01
38	C	5	4.03	5	4.45
39	C	5	3.46	5	3.26

Category A:	Features associated with structural characteristics of a textbook
Category B:	Features which reflect social concerns
Category C:	Features which are related to cognition
Author Scale:	5 = 'Very Important'
Student Scale:	5 = 'Used all the Time'

TABLE 2

RESULTS OF TESTS TO DETERMINE THE DIFFERENCE BETWEEN AUTHOR'S INTENDED USE OF TEXTBOOK FEATURES AND STUDENTS' PERCEPTION OF THE EXISTENCE OF THESE FEATURES IN A TEXTBOOK

Category of text Feature	Number of Items	Test of Signif. Used	Book 1		Book 2	
			Stat Value	Signif.	Stat Value	Signif.
Structural	8	White Critical Point	40	<0.01	44	<0.05
Social	6	White Critical Point	28	<0.07	21	<0.01
Cognitive	20	Chi Square df = 1	5.28	<0.05	13.53	<0.01

$p < 0.10$ accepted

The implications of this conclusion, when extrapolated to Junior Science Textbooks in general, are important for authors, students and teachers. One assumes that authors choose structural, social and cognitive features of their textbooks for sound educational reasons. However, if students cannot even recognise the existence of these features, then it is most unlikely that they will be able to use their textbook efficiently in the manner in which the author intended.

Perhaps authors assume that teachers will draw students' attention to the significance of the textbook features used? If this is so, then these results show that this is not occurring. Perhaps teachers themselves are unaware of the existence of these features? Obviously, more research needs to be carried out in this area.

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PERSISTENCE AND WITHDRAWAL BY STUDENTS IN A PRESERVICE SCIENCE AND MATHEMATICS TEACHER EDUCATION COURSE

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ABSTRACT

At a time when recruitment into preservice teacher education courses in mathematics and science is difficult, one strategy to increase the number of graduates is to minimise the number of students who fail to complete their university courses. This study sought to determine factors which distinguish withdrawers from persisters in the first semester of a B.Ed course. Discriminant analysis was employed; a discriminant function employing seven factors resulted in correct classification in 81% of cases. Further analysis distinguishing between dropouts and transferees resulted in two discriminant functions with some common variables.

INTRODUCTION

There is a persistent and serious shortage of mathematics and science teachers in Australia, particularly in Physics, Chemistry, and Senior Mathematics (Department of Employment, Education and Training, 1989, pp. 168-170; Board of Teacher Education 1985, pp. 1-7). The dropout rate from preservice teacher education courses in these teaching areas undoubtedly exacerbates the situation which results from the failure to recruit sufficient numbers of students to meet projected demand for teachers.

Acceptance of a high level of dropout from undergraduate courses in Australia is widespread. While there are isolated examples of individuals or institutions attempting to reduce the dropout rate, it is commonly assumed that students who drop out are incapable of success for one or more of a variety of reasons. Attempts to predict individual students' withdrawal, from knowledge of specific personal and background characteristics, have met with very limited success.

An unpublished 1989 report by the Brisbane College of Advanced Education (Report of the Academic Board Working Party on student admissions) on students withdrawing from tertiary courses indicates that significant numbers of students with high tertiary entrance scores are included. These are students who could be expected to be quite capable of completing the course. West et al. (1986, p. 153) emphasise the futility of seeking a set of variables that will successfully predict those who will drop out, because the variables do not have simple effects. Nevertheless, if there were a greater understanding of the interactions between these factors it might be possible to implement preventative or remedial interventions which would increase graduation rates and help to boost the number of mathematics and science teachers in Australia.

This paper reports early findings from a longitudinal study of science and mathematics students in a four year B.Ed. course at Queensland University of Technology.

The study commenced in January 1991; it addresses the question, what factors distinguish withdrawers from persisters in the B.Ed course?

TABLE 1
VARIABLE DEFINITIONS AND DERIVATIONS

	Variable	Derivation
1.	Gender	Male/Female.
2.	Tertiary Entrance Score (TESC)	Actual score.
3.	Expectation of social acceptance by peers (SOCEXP)	Questionnaire response. 1 Item.
4.	Level of financial concern (FINCON)	Questionnaire response. 1 Item.
5.	Openmindedness score. (OMSC)	Score on Rokeach Dogmatism scale. 40 Items.
6.	Academic Locus of Control (ALOCSC)	Score on Trice Academic Locus of Control Scale. 28 Items.
7.	Level of aspiration (STUASP)	Score on aspiration scale of DOSC Form H. 16 Items.
8.	Anxiety (STUANX)	Score on anxiety scale of DOSC Form H. 16 Items.
9.	Academic interest & satisfaction (STUACAD)	Score on academic interest and satisfaction scale of DOSC Form H. 16 Items
10.	Leadership and Initiative (STULEAD)	Score on leadership and initiative scale of DOSC Form H. 16 Items.
11.	Identification versus Alienation (STUIDEN)	Score on identification versus alienation scale of DOSC Form H. 16 Items.
12.	Personal aspirations towards teaching (ASPTEA)	Questionnaire responses. 4 Items.
13.	Personal aspirations other than teaching (ASPNOTEA)	Questionnaire responses. 10 Items.
14.	School satisfaction (SSATSCO)	Questionnaire responses. 10 Items.
15.	Socio-educational status of parents. (SOCEDST)	Questionnaire responses. 4 Items.
16.	Influence to become a teacher by family & friends (FAMINF)	Questionnaire responses. 3 Items.
17.	Influence to become a teacher by school people (SCHINF)	Questionnaire responses. 3 Items.
18.	Influence to become a teacher by job related factors. (JOBINF)	Questionnaire responses. 2 Items.
19.	Expectation of academic integration. (EXPACIN)	Questionnaire response. 1 Item.
20.	Enrolment status (CURENR)	University records at the end of semester 1. 1 Item.

METHOD

Sample The sample for this study comprises the 113 commencing students in the B.Ed. course who selected one or both teaching areas from science and mathematics. A small number of late commencers were not included because they did not complete the initial data collection phase during the orientation program.

Instruments Data were collected during orientation week by way of a questionnaire, a Test of Openmindedness (OM) (Rokeach, 1960), an Academic Locus of Control Scale (ALOC) (Trice, 1985), and a Dimensions of Self Concept Scale (DOSC-Form H) (Michael et al. 1984). The questionnaire was developed to gather information pertaining to students' academic and personal backgrounds.

Variables Identification of the variables to be included in the study was influenced by previous studies of student persistence based on theoretical models of Tinto, and Eccles (Tinto, 1975; Williamson & Creamer, 1988; Stoecker et al., 1988; Eccles, 1983; Ethington, 1990). The current status of student enrolment was determined by inspection of student records after publication of semester 1 results. Students were classed as "withdrawers" when their records showed that their enrolment was no longer current in the mathematics/science units which they had commenced at the beginning of the semester. Variables included in the study are summarised in Table 1.

RESULTS

In this study, no significant difference was evident between males and females on the dependent variable, nor were there consistent gender differences in the mean scores on independent variables. Consequently the male and female data were pooled. Discriminant analysis was employed in order to compare the characteristics of persisters and withdrawers from the first semester of a B.Ed. course. Independent variables were Tertiary Entrance Score (TESC) to Expectation of Academic Integration (EXPACIN) as shown in Table 1. The dependent variable was Enrolment Status (CURENR). Analysis utilised the SPSS-X Discriminant program with Wilks' stepwise variable selection procedure and prior probabilities established by group sizes.

One discriminant function equation was generated by the SPSS-X Discriminant procedure. Order of entry of variables, values for Wilks' lambda and associated significance levels are listed in Table 2. One canonical discriminant function was formed with group means of -0.25590 for persisters and 0.94897 for withdrawers. Table 2 also lists standardised canonical discriminant function coefficients and pooled within groups correlations between the seven variables and the discriminant function.

In order to interpret these results it was decided to consider only variables with absolute values for both standardised coefficients and correlations above 0.3. This procedure is consistent with guidelines given by Stevens (1986, pp. 232-243) whereby the discriminant function-variable correlations are used for substantive interpretation and the standardised coefficients are used to determine which of the variables are redundant. The critical value of 0.3 chosen for correlations is at the lower end of the moderate range (Stevens, 1986, p. 242). The same value was adopted for the coefficients given the apparent lack of conventional guidance in this respect. It is acknowledged that although the variables ASPTEA, SCHINF, and STUASP contribute

TABLE 2
DISCRIMINANT ANALYSIS, TWO GROUPS: WILKS' LAMBDAS, STANDARDISED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS, AND POOLED WITHIN-GROUPS CORRELATIONS BETWEEN DISCRIMINATING VARIABLES AND DISCRIMINANT FUNCTION

Variable	Wilks' Lambda	Sig	Standardised Coefficient	Pooled within Groups r
EXPACIN	.93336	.0058	-.62610	-.53741
FAMINF	.90021	.0031	-.49153	-.44263
ALOCSC	.87423	.0021	.57737	.47891
ASPTEA	.84340	.0010	.43150	.05920
SCHINF	.82664	.0009	.39464	.08772
STUASP	.81719	.0013	.36738	-.05725
ASPNOTEA	.80179	.0013	-.35001	-.37232

significantly to the linear function, they do not correlate with the discriminant function variable, possibly because of the presence of a suppressor variable. These variables were therefore excluded from further consideration. Table 3 lists group means and standard deviations for the variables retained for interpretation of results.

TABLE 3
GROUP MEANS AND STANDARD DEVIATIONS ON SELECTED VARIABLES FOR PERSISTERS AND WITHDRAWERS

Variable	Persisters		Withdrawers		F	Sig
	Mean	SD	Mean	SD		
EXPACIN	13.15	1.75	11.88	2.63	9.799	.002
FAMINF	5.11	2.97	3.54	2.86	3.789	.054
ALOCSC	8.54	4.03	10.88	4.11	6.385	.013
ASPNOTEA	26.62	4.84	24.42	5.15	4.700	.032

Examination of group means in Table 3 suggests that, compared with persisters, withdrawers had lower levels of expectation of academic integration into their university course, lower levels of personal aspiration to achieve in areas other than teaching, and less influence towards enrolling in the B.Ed from family and friends. The higher score for academic locus of control indicates relatively higher levels of extrinsic motivation. Based on the discriminant function involving the seven variables named in Table 2, predicted group membership was found to be correct in 81.4% of cases. Table 4 reports the group membership predicted by the discriminant function scores and the distribution expected by chance.

TABLE 4
PREDICTED AND CHANCE GROUP MEMBERSHIP: TWO GROUPS

Actual Group	Number of Cases	Persisters	Withdrawers
Persisters	89	84 (79)*	5 (10)
Withdrawers	24	16 (21)	8 (3)

* Numbers in parentheses show the distribution expected by chance.
Chi-square: 12.34, df = 3, p< 0.01

Further inspection of the cases classified as withdrawers revealed two distinct subgroups, namely fifteen students who had withdrawn totally from the B.Ed course and nine who were still enrolled in the B.Ed course but who had transferred from mathematics or science specialisations to other curriculum areas. As it seemed likely that students in these two subgroups could differ on some of the independent variables, a second discriminant analysis was performed with three groups, namely persisters in the B.Ed. (maths/science), dropouts, and transferees within the B.Ed. Two discriminant function equations were generated by the SPSS-X Discriminant procedure. Group means for the two discriminant functions are listed in Table 5. Order of entry and summary details relating to these variables and functions are listed in Table 6.

TABLE 5
GROUP MEANS ON FUNCTION 1 AND FUNCTION 2 FOR PERSISTERS, DROPOUTS, AND TRANSFEREES

Group	Function 1	Function 2
Persisters	-0.19889	0.17295
Dropouts	1.36459	-0.06665
Transferees	-0.30750	-1.59921

In interpreting these results only variables with absolute values for both standardised coefficients and correlations above 0.3 were considered, in light of the rationale previously outlined. Table 7 lists group means and standard deviations for the five variables meeting this criterion.

Examination of Tables 5, 6 and 7 reveals that two variables, ALOCSC and EXPACIN, contributed to factor 1 and that factor 1 scores discriminate between dropouts and the other two groups: dropouts had relatively higher levels of extrinsic motivation. Compared with persisters, dropouts and transferees had lower levels of expectation of academic integration into their university course.

TABLE 6

DISCRIMINANT ANALYSIS, THREE GROUPS: WILKS' LAMBDAS, STANDARDISED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS, AND POOLED WITHIN-GROUPS CORRELATIONS BETWEEN DISCRIMINATING VARIABLES AND DISCRIMINANT FUNCTIONS

			Function 1		Function 2	
Variable	Wilks' Lambda	Sig	Standardised Coefficient	Pooled within Groups Correlation	Standardised Coefficient	Pooled within Groups Correlation
ALOCSC	.92853	.0169	.84374	.49608	.07176	-.14164
STUANX	.88593	.0101	-.54427	-.12454	-.41570	-.40836
STUACAD	.82760	.0021	.59689	-.06830	.82429	.37294
SSATSCO	.79065	.0013	.14415	.18336	.50193	.31982
EXPACIN	.75688	.0008	-.49469	-.38285	.44320	.35151
ASPTEA	.72743	.0006	.26352	.04125	-.32533	-.03976
FAMINF	.70294	.0006	-.47573	-.27563	.17318	.33503
SOCEXP	.67975	.0005	-.25929	-.31832	-.42446	-.11856
SCHINF	.65609	.0005	.51843	.12051	-.13533	.00922
STUASP	.63911	.0006	.15449	-.12921	-.55120	-.06406
ASPNOTEA	.62639	.0008	-.24713	-.28951	.28425	.21580

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TABLE 7
GROUP MEANS AND STANDARD DEVIATIONS ON SELECTED VARIABLES FOR PERSISTERS, DROPOUTS, AND TRANSFEREES

Variable	Persisters		Dropouts		Transferees		F	Sig
	Mean	SD	Mean	SD	Mean	SD		
ALOCSC	8.54	4.03	11.80	3.12	9.33	5.22	4.204	.017
STUANX	43.39	9.53	42.47	10.34	50.44	8.49	2.431	.093
STUACAD	49.38	7.16	47.93	8.03	45.56	8.52	1.832	.165
SSATSCO	28.42	4.56	29.40	4.12	25.67	6.60	1.744	.180
EXPACIN	13.15	1.75	11.80	2.37	12.00	3.16	4.936	.009

Four variables, STUANX, STUACAD, SSATSCO, and EXPACIN contributed to factor 2. Factor 2 scores discriminated between transferees and the other two groups. Compared with persisters and dropouts, transferees had higher anxiety, lower levels of academic interest, and were less satisfied with their school experiences. The transferees' group mean for level of expectation of academic integration into their university course was lower than that for persisters and marginally higher than that for dropouts. Group membership predicted by the two discriminant functions was found to be correct in 85.0% of cases (Table 8). In this analysis, which separated dropouts and transferees, the accuracy of prediction of dropouts has been increased over that reported in Table 4.

TABLE 8
PREDICTED AND CHANCE GROUP MEMBERSHIP: THREE GROUPS

Actual Group	Number of Cases	Persisters	Dropouts	Transferees
Persisters	89	87 (80)*	1 (6)	1 (3)
Dropouts	15	9 (13)	6 (1)	0 (1)
Transferees	9	5 (8)	1 (1)	3 (0)

* Numbers in parentheses show the distribution expected by chance.

DISCUSSION

This study points to several factors which may help to promote a better understanding of the phenomenon of student withdrawal from preservice teacher education courses. These are academic locus of control, expectation of academic integration, influence of family and friends to enrol in a B.Ed. level of student anxiety and personal aspirations other than teaching. It is not suggested that these variables relate to student withdrawal in a simple manner. However, if further studies confirm the importance of these variables, academic advisers and others concerned to increase the rate of graduation of science and mathematics teachers may seek to intervene in appropriate ways. This study is limited by small group sizes especially when dropouts and transferees are identified. It will be extended through the second semester of the course, when it is anticipated that the dropout and transferee groups will increase in size. It is also intended to replicate the study with a larger and more diverse group of first year students in future years to enable investigation of the stability and general applicability of the discriminant functions.

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REGISTERED NURSES' CONSTRUCTED MEANING OF CONCEPTS OF SOLUTION AND THEIR USE IN CLINICAL PRACTICE

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ABSTRACT

Since the introduction of nursing into tertiary institutions in Australia in 1975, there has been increasing interest in the teaching of physical science to nurses. Various courses in physical science for nurse students have been developed. They vary in length and content but there is agreement that concepts taught should be closely related to nursing applications. The choice of relevant concepts tends to be made by individual curriculum developers. This paper reports an examination of the use of physical science concepts and their relevance from the perspective of registered nurses practising in general ward areas. Inherent in this study is the premise that for registered nurses to have ideas of the physical science underlying their practice they must have constructed meaning first for these concepts. Specific chemical concepts related to solutions are discussed in these terms.

INTRODUCTION

Since the introduction of nurse education into tertiary institutions in Australia in 1975, the emphasis in nursing programs has been to develop a relationship between theory and practice which will result in the production of a safe and effective nurse practitioner. It is stated in The Goals in Nursing Education (Donaghue, 1976) that

> the purpose of nurse education is to prepare nursing practitioners by programs designed to provide theoretical content and practical experience that enable graduates to practise at a level which meets the needs of effective nursing care (p 11).

According to Targets in Nurse Education (Chandler, Cochrane & Ryan 1990), preregistration programs for nurses should be a minimum of three years and be at the Bachelor level. These courses must

> prepare women and men for beginning level practice as registered nurses .....; provide education preparation with foundation studies in nursing, the sciences and the humanities; and enable the development of clinical nursing competence and communication, conceptual, analytical and problem solving skills commensurate with the profession's standards. (Appendix 3.1)

While there appears to be agreement that there should be a physical science component in tertiary nursing programs, the time allotted to it varies greatly. Barclay and Neill (1987) found, in a survey of 11 institutions, that the physical science content was similar in terms of topics but not in content and that course hours varied from minimal to 96 hours. Paix (1989), in a national survey of nursing programs in Australia, across 15 institutions, reported that the physical science hours ranged from 20 to 120 hours. McAulliffe (1987) concluded from a survey of seven institutions in New South Wales that the major factors influencing the science content of the nursing programs were the science background of the curriculum(s) developer and the standing and academic reputation of the service. school. McAulliffe (1987) recommended that a study should be done to show whether there is any correlation between what is taught in the science component and what is required in nursing practice (p 71). The relevance of applied science to clinical practice in nursing and medical education has been questioned by a number of authors in Medicine (Sukkar 1984, Duban et al. 1982, West et al. 1982, Maddison, 1978) and in Nursing (Barclay & Neill 1987, Wong 1979, Smillie & Arlie, 1978). Dori (1988) in discussing chemistry courses for nurses states that curriculum developers must take into consideration:

- the needs of those undertaking a number of nursing activities in hospitals and clinics and more advanced nursing courses such as pharmacology and physiology
- the weak background in mathematics and science of nursing students in general
- the need to raise the low motivation of nursing students to learn chemistry by making it relevant to the profession.

A. Stewart (personal communication), a nurse educator with no science major, when asked if she felt nurses needed to know chemistry and physics, produced a line diagram of some 50 science concepts. She had developed this diagram as a background to her science teaching in a hospital based program in 1980.

Townsend (1991) asserts that nurse practitioners of the future must be different in that

> they must be able to function independently, working autonomously, making their own decisions, initiating their own treatments and controlling their own professional, political and personal destinies (p 263).

The profile of the registered nurse which emerges from this discussion requires that the nurse be a professional who has the knowledge and research background to act as a decision maker and care giver in a number of health/illness settings. Within the profession, both administrators and educators confirm that the knowledge base of nursing should embrace studies in nursing, the sciences and the humanities at the conceptual, problem solving level. Rote learning will not serve the interests of the student wishing to develop this profile of the future nurse nor will it fulfil the expectations of the general public (Hamilton, 1990). To attain these goals in educational programs for nurses there is a need to use the world of nursing as a template for curriculum development. Nursing as a profession recognises that the various science and humanities disciplines, moulded by the genuine needs of nursing, can contribute greatly to this development.

The aim of our continuing study is to determine what physical science knowledge registered nurses have and how they use this knowledge in their clinical practice. This will provide a background from which future curriculum developers of science for nurses can work. In this paper we report an examination of the use of physical science concepts and their relevance from the perspective of registered nurses practising in general ward areas.

METHOD

Field work has been the research approach in this project. It was undertaken in the natural environment of general ward areas in six metropolitan hospitals in Sydney. Fifty-eight registered nurses participated in the study. They were graduates from either hospital or college/university preregistration programs. The sample was a nonprobability, purposive one in that the nurses were selected on the basis that they worked on a morning shift in a general ward area on a day when the researcher was available.

Data were collected from each subject by researcher observation and individual subject diaries. The researcher observed each nurse for 1.5 hours in his/her normal ward environment, noting all activities undertaken by the subject in that time. At the end of the observation period the subject was interviewed for approximately ten minutes and asked to talk of any chemistry and physics which the subject felt he/she had used in relation to the activities noted by the researcher. Each subject was asked to enter into a notebook provided, his/her perceived use of any chemistry and physics concepts over a subsequent period of a week and if possible to note the specific concepts.

FINDINGS

The results are based on 58 observations and 28 diaries. The sample consisted of 7 males and 51 females of whom 35 had Diploma/Degree nursing qualifications and 23 had Certificates in nursing. The written scripts of the observations and the diaries were coded by the researcher and the coded texts sorted using The Ethnograph Program (Seidel, Kjolseth & Seymour, 1988) on an IBM personal computer. This has allowed the categorisation of nursing activities and physical science concepts; 46 distinct nursing activities were noted and their frequency of occurrence in the observations and diaries has been recorded. The most common nursing activities overall are those related to medications (preparation and administration), intravenous therapy, lifting, blood pressure and blood analysis. The physical science concepts used in the context of all the observed nursing activities have been categorised into 17 fields (Fig. 1). From the frequency of occurrence of these fields in the observation and diaries, the five most common have been identified. They are fluid flow, pressure, measurement, solution and motion.

For the purpose of this paper the physical science concepts with the field of solution and the application by the subjects of concepts have been chosen for discussion. Exemplars from data are used in this analysis. Solution was mentioned 37 times overall in 13 diaries. There were 46 incidences of solution concepts related to nursing activities observed in the wards which were recorded by the researcher in interviews of the subjects. The concepts mentioned most often were normal saline, making up solutions, osmosis, diffusion, dehydration/hydration, solubility, and isotonicity. It is interesting to note that this list of concepts could have been derived from the terms related to solution shown in the line diagram developed by A. Stewart. In relation to solutions, she listed as significant, the terms dissolving, fluid compartments, fluid movement, concentration and fluid balance.

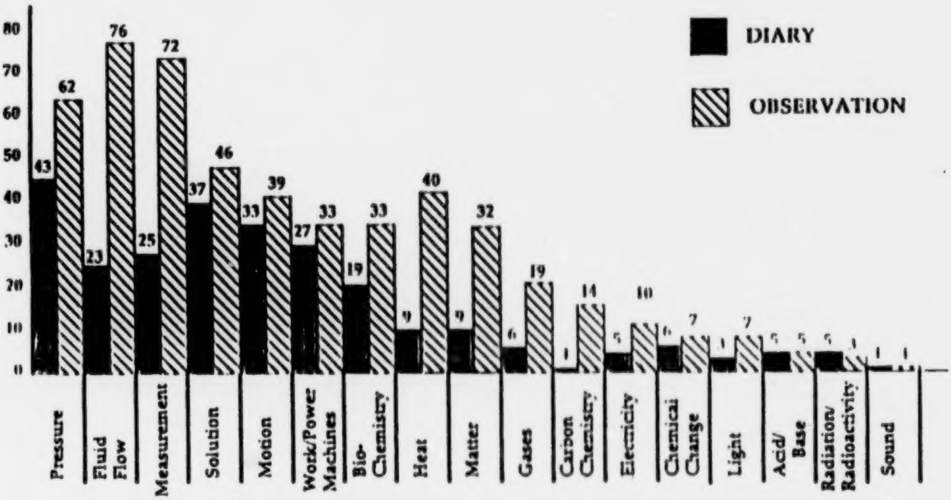

Fig. 1 Frequency of occurrence of 17 physical science fields identified from the nursing activities of a sample of registered nurses in general ward areas.

Many of the concepts used by the nurses are interrelated. "Normal saline" is a term which occurs frequently in the context of other solution concepts. Ideas about "making up solutions" and "solubility" have been expressed by the subjects as in the following exemplars.

(Exemplars are coded: O - observation; D - diary; A - diploma/degree;
B - certificate)

* mixing IV antibiotics - water dissolves powder. (D,A)
* mixing drugs with water is chemistry. (D,A)
* mixing drugs - concentration (D,A)
* water used to mix Fluxacillin - more neutral than normal saline (O,A)
* mix antibiotic with water to insure no sediment - soluble in water, compatible with water (D,A)
* Keflex is dissolved in water because that is what is on the label. (O,A)
* water is used to mix injections, I always use it; it's the same as normal saline. (O,B)
* to make up injections I use normal saline for powders, water for liquids. (O,A)
* to make up injections I mix powder with water, liquid with normal saline. Don't know why. (O,A)
* water dissolves powder. (D,A)

Most of the concepts used when making up solutions whilst being rather simplistic are not wrong but the nurses appear to use rote learned procedures such as that expressed in the exemplar relating to Keflex: what is on the label is more important than why one is using water. Some of these learned protocols, as in the last three exemplars, are contradictory. It is evident these nurses are aware of the concept of solubility but not necessarily of solubility properties. They know that things dissolve but they either do not know why or they do not consider the "why" in rationalising their actions. Concepts of matter such as polarity or ionisation are not mentioned in discussing solutions. An awareness of these concepts may have given the nurses rationales for the use of particular solvents when making up solutions. Concentration is expressed as important by only one nurse but from the following exemplar it would seem again that it is a learned protocol:

* during the drug round - I need to know the strengths and dilutions of drugs; e.g. 0.5 mL gives me 100 mg. (D,A)

Concepts related to dehydration and hydration are used by the nurses specifically in giving fluid replacement and monitoring it.

* dehydrated kid having IV fluids...chemistry (D,B)

* hydration status measured by CVP - indicates the amount of fluid in the venous system. (O,A)

* IV fluids regulated to hourly urine output - indicates hydration level. (O,A)

* I need to know the relationship between hydration, electrolytes and IV fluids. (O,A)

By making these statements the subjects acknowledge that there is a relationship between the giving of fluids and hydration. They do not explain the relationship or identify the types of solution used to maintain the volume in the venous system. One nurse in her diary made a generalised statement:

* fluid challenge, volume expanders - chemistry (D,A)

Perceptions related to fluid movement - osmosis and diffusion - are often expressed by use of the term "isotonic". The following exemplars show this.

* flushing cannula - normal saline used; isotonic to blood (D,A)

* use normal saline to irrigate and clean wound; safe to use; isotonic to blood (D,A)

* bladder irrigation - osmosis and diffusion; normal saline isotonic to blood (D,A)

* normal saline used to irrigate and clean wound; no reason for saline specifically (O,A)

- normal saline used to clean the skin; water could be used; saline has some antiseptic properties. (O,B)

The nurses have labelled saline/normal saline as isotonic without giving reasons for its use. It may well be that in cleaning a wound the disinfectant properties of saline solution are more important than its isotonicity. The strength of the saline is also ambiguous. In practice in the wards normal saline is 0.9 % w/v sodium chloride.

Some nurses do show an ability to give reasons for their actions and this can be seen in the following exemplars:

- IV push - normal saline used instead of water - it will cause osmosis; normal saline isotonic (O,A)

- hypertonic saline is more concentrated than normal saline; it's used to reduce swelling; it attracts water from the cells. (O,A)

- bladder irrigation - normal saline used; it's closest to the blood; water will cause osmosis; saline is isotonic. (O,B)

Two nurses, who were the exception, showed they could link concepts in a complex manner and relate the complete body process and osmosis:

- glucose...[in blood]...can cause a high urine output because of osmosis. (O,A)

- salt water mouth wash kills bacteria. It dehydrates the bacterial cells by osmosis. (O,B)

Other statements such as

- sodium chloride is used to flush IV cannula instead of water because it causes pain (O,A)

are erroneous and not related to chemistry or practice in any way. Some nurses use terms which have been accepted in practice, but which are not correct in scientific terms. This corruption of the language of physics and chemistry is evident particularly in pharmacology and physiology. An example of this is

- enema - use an osmotic fluid to draw fluid out of the body. (D,B).

This statement refers to a solution of mannitol or urea at a concentration which is very hypertonic. The term "osmotic fluids" for hypertonic solutions is socially accepted in the workplace.

DISCUSSION

Most of the registered nurses in this study show a use of physical science concepts which is very simplistic. They do not go beyond forming links between concepts. They do not explain the links or expand on them. For example they link "label" with "making up solutions", "saline" with "isotonic", and "water" with "osmosis". They tend to use these textbook terms without being able to explain them in commonsense language. Happs (1985) stated that learners often replace formal knowledge with commonsense knowledge. He goes on to say that "adults may currently have a knowledge of science that is heavily flavoured with original intuitive (commonsense) perspective" (p 442). The usage of concepts by the nurses in this study appears ritualised rather than intuitive. They are prone to use rote learned rules rather than reasoned action.

The subjects in this study have constructed simple meanings of physical science concepts which they find serve them in the workplace. They have found that ritual is not in conflict with their constructed meaning and the ritual has become their construct. This accords with the model of Osborne and Wittrock (1983) which suggests that learning is not a passive process. Links must be made with information in long term memory and these links must be considered useful by the learner otherwise there is no change in conception (i.e. learning).

The workplace is not the only influence on the nurses' construction of physical science concepts. A major contributing factor is language. The variation in language used in different disciplines of science to describe the same physical process does not always help anyone to construct difficult concepts in long term memory. Nurses have a physiological perspective on science terminology which is encouraged by textbooks. For example, Havard (1987) uses "osmotic agents" as a general term for hypertonic solutions of particular reagents. Language used in the nursing literature can be misleading and is sometimes scientifically inaccurate. For example, Sommers (1990) wrote "the pressure... [intravascular colloid osmotic pressure]... of plasma proteins pulls fluid from the interstitium back into the bloodstream" (p 90).

From the exemplars in this paper it is evident that many nurses have the same constructed meaning for particular physical science concepts. Propositions such as "saline is isotonic to the blood" support the premise of Driver and Bell (1987) that

> there are patterns in the types of meanings students construct due to shared experiences within the physical world and through natural language (p 453).

The nurses in this study present conceptions of physical science which are not appropriate if the future nurse is to be autonomous, a decision maker and an initiator of treatment. To acquire these characteristics, the nurse needs to develop conceptual, analytical and problem solving skills (Chandler, Cochrane & Ryan, 1990). A knowledge of physical science at the level of ritual will not provide these skills.

This study has been limited in that, with the restricted time available in the ward situation, no in-depth probing of the nurses' conceptions of the application of physical science concepts to clinical practice has been possible. On interviewing a small number of nurses to assess in more detail their constructs of physical science, it appears still that ritual is the basis for the majority of their actions. There is evidence that some nurses sometimes use more complex organisation of concepts and can relate them to their practice in a purposeful manner. Bishop (1990) proposed that a general lack of ability in student nurses to make the transition from rote learning to the application to nursing of scientific facts and principles may be because science teaching at school relies on memorising information.

To foster application of physical science concepts in nursing, it is important for teachers of physical science in tertiary nursing programs to use clear contextual examples from clinical practice. It is also important for these teachers to collaborate across disciplines to come to some agreement on terminology to be used and the context of its use. Hamilton has posed a question in relation to the teaching of science to nurses which seems to require an either/or answer.

> Is science to be presented simply as a series of topics to serve the needs of nursing units or should students understand science as a discipline? (p 28)

We propose that teachers of nurses from all disciplines should work together to fulfil the interests of both nursing and science. By consulting practising registered nurses, teachers will develop an understanding of the nurses' perceptions of science and identify the needs of the nurse of the future. The student who accepts the challenge of the discipline of science will be the independent nurse practitioner of the future.

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This research proposal has been reviewed and accepted by the Ethics Committees of the six hospitals involved in the study. We wish to thank the administration of these hospitals for their assistance in this project.

We are pleased to acknowledge the cooperation of the 58 nurses who allowed us to observe their work and thank them for help given in their own time in fulfilling other requirements of this research.

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GIRLS, BOYS AND CONCEPTUAL PHYSICS: AN EVALUATION OF A SENIOR SECONDARY PHYSICS COURSE.

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Dickson College

ABSTRACT

This paper reports an evaluation of the physics course at Dickson College (ACT) looking at students' high school experience, their expectations before beginning and their impressions and feelings during the course. In general, students seem to have a fairly negative approach to physics, enrolling for a variety of often vague utilitarian reasons but with little expectation of enjoyment or interest. These opinions were most prevalent in girls who tend to find the content difficult and the course as a whole uninteresting. There is also a significant difference between girls and boys in their response to different types of assessment items. In an attempt to enhance the level of interest and enjoyment in students we have been phasing in a more 'conceptual' approach to the teaching of physics.

INTRODUCTION

In 1989 the Science and Technology Education Working Group in the ACT commissioned a study of Year 12 students. This highlighted the numbers of male and female students completing secondary courses, including physics, required for entering tertiary courses in science and technology. The ACT Schools Authority (now the Education Department) follows a strong policy of gender equity in education and has allocated staffing and in-service resources to this end. However, since 1984, despite such programs there appears to have been no improvement in female participation in Level 1 (the top level) Mathematics, or in Physics, Chemistry or Computing. In fact, most girls continue to avoid the option of studying these subjects at senior secondary level in the ACT. Around 12% of girls compared with 40% of boys choose a major in Physics in their tertiary packages. These figures have remained static since 1984 (Foster, 1989).

Schools in the ACT develop their own curricula. Each course must be re-written and submitted for accreditation every 5 years. The accreditation process involves (in order):

- a course evaluation in the school, with the participation of teachers, students and community members;
- approval by the School Board;
- examination by an Accreditation Panel; and finally
- acceptance by the ACT Board of Studies.

The Accreditation Panels are made up of teachers, together with community and tertiary representatives. Physics assessment has been largely test-based, while Physics courses themselves have remained mostly content-driven and teacher-centred. Some secondary colleges have recently introduced Physics courses with more emphasis on student participation. These courses, however, have been largely school-initiated developments rather than a response to pressure from the Physics Accreditation Panel.

The Evaluation

Dickson College is a state secondary college in the ACT catering for around 830 Year 11 and 12 students. Some 30% of the Year 10 cohort go on to take at least one year of physics; the majority are boys. A slightly lower proportion of girls than the ACT average completes a Physics major. In 1990, we carried out an evaluation of our current Physics course in an attempt to determine the reasons why students chose Physics, and their impressions of the course after at least one year of study. A questionnaire was administered to 130 students (both year 11 and 12) who had completed at least 8 months of our Physics course. The sample included 78 males and 41 females (11 did not indicate sex). The questions asked and possible responses are described in the figure legends.

An earlier study (Note 1) showed that the majority of students chose Physics mainly for utilitarian reasons. The present study corroborates this finding. Fig. 1 shows the reasons given by students for choosing Physics.

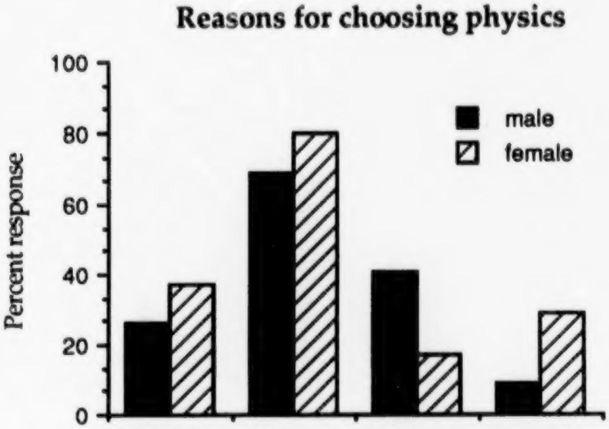


Figure 1 - Students were asked to identify their reasons for enrolling in Physics. Possible responses were: the high marks, might need it for the future, thought you might enjoy it, parents wanted you to. Students were able to select more than one response.

Though most answered that they "might need it in the future" (for most a vague concept), very few, in fact, intended continuing their studies in any physical science course at a tertiary level. Most students seem to be responding to advice given by teachers at high school and, in the case of many girls, to parental pressure. Relatively few expect to enjoy studying Physics despite the fact that most remember science at high school as an enjoyable experience (Fig. 2). Girls in particular seem to have low expectations of Physics. It has been suggested that "boys are more likely to continue with a subject they dislike or are having difficulty with, because they believe it is necessary for their future career" (Kearney & MacDonald, 1987, p.9). Our own results suggest that even amongst the girls choosing to study physics, very few expect to enjoy it (Fig. 1) and, in fact, persevere despite fairly negative feelings towards it (Fig. 3). When compared to boys, our girls tend to find Physics less interesting (Fig. 4), less relevant (Fig. 5), and more difficult to understand (Fig. 6). Many girls are quite prepared to endure a subject they do not enjoy for what is often a vague future benefit. A disturbingly high proportion of students still choose to study Physics only because they expect to gain higher marks than in other subjects.

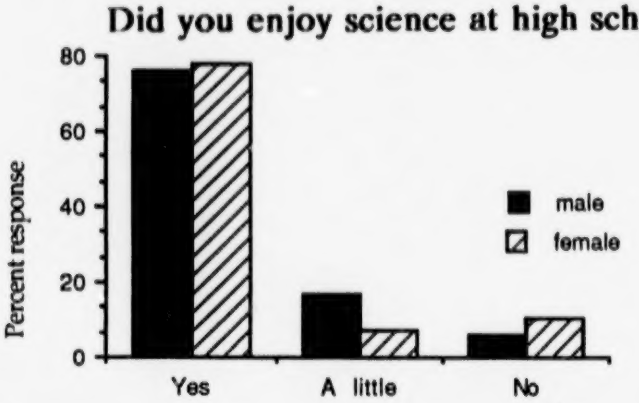


Figure 2 - Students were asked whether they enjoyed science at high school.

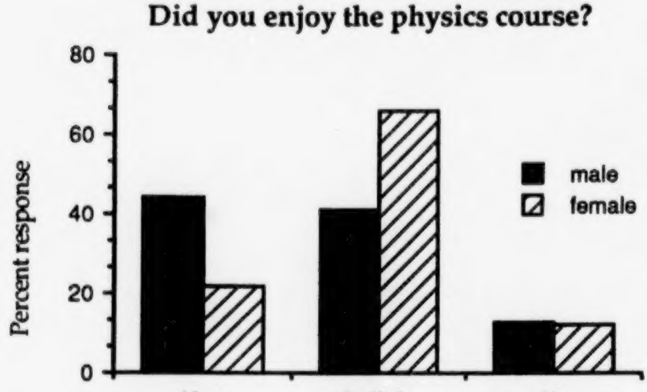


Figure 3 - Students were asked 'Have you enjoyed the Physics course?'

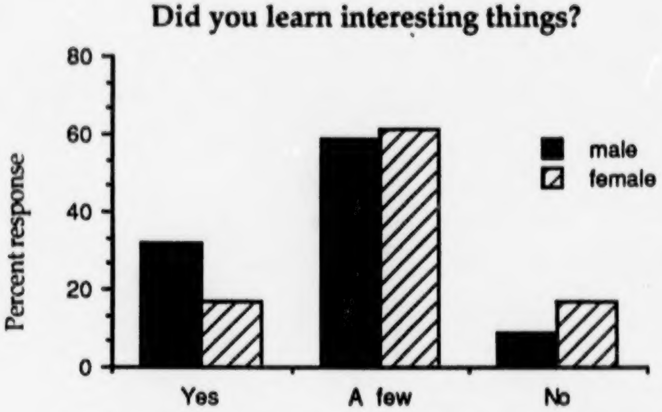


Figure 4 - Students were asked 'Did you learn many interesting things?'

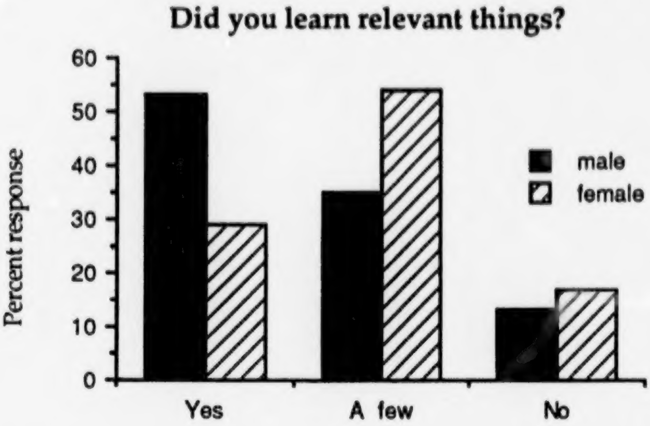


Figure 5 - Students were asked 'Do you think you learned things relevant to everyday life?.

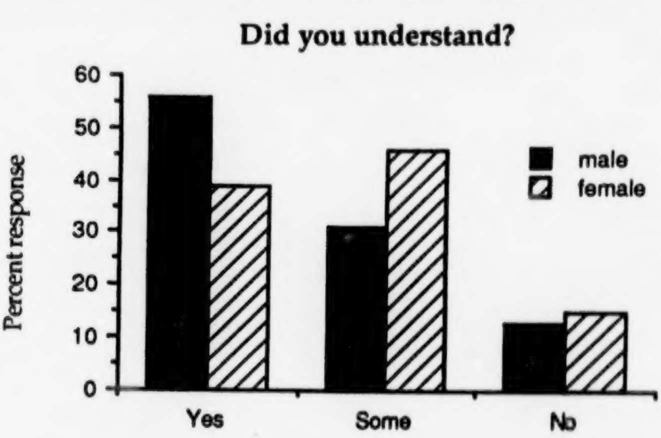


Figure 6 - Students were asked 'Do you feel that you understood most of the things taught?'

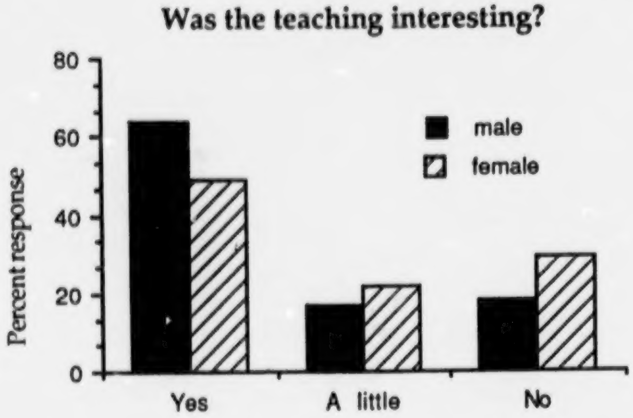
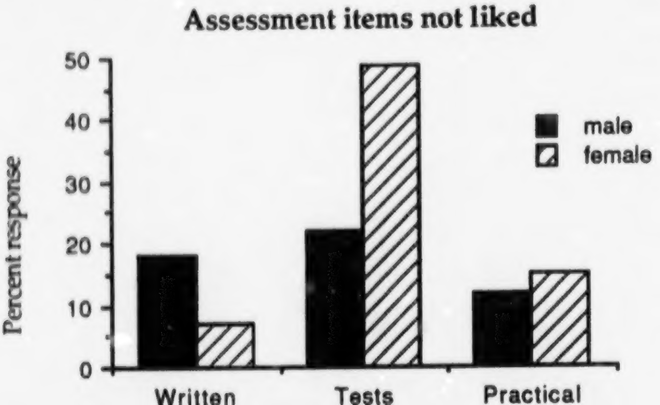


Figure 7 - Students were asked 'Overall, did teachers teach in an interesting way?'

Carrying out this study has brought one problem to the fore: in general, students seem reluctant to criticize a Physics course, either in its form or in the way it is taught. We have observed that they enrol with the expectation that a 'good' Physics course will be difficult, possibly incomprehensible, boring, and that a large amount of time will be spent in solving quantitative problems. This has made it hard to analyse the less formal evaluations carried out previously. When students were asked 'Did you learn many interesting things?' their responses were quite negative (Fig. 4), but the question 'Did the teachers teach in an interesting way?' elicited a much more positive response (Fig. 7). Similarly, although the difference was less extreme, both girls and boys responded more positively to 'Were the teachers easy to understand?' than to 'Do you feel that you understood most of the things taught?'. It would not take much flight of fancy to sum up a typical response from a Physics student as: "The course was boring and I didn't understand much of what went on. We spent a lot of time doing boring problems. It was a very good course and was well taught." Based on previous, less formal, evaluations we have gained the impression that students often fail to appreciate the real-world problem-solving that a more constructivist approach would allow. They tend to equate difficulty with boredom, value with quantitative problems, and enjoyment with time-wasting.



In short, students have very conventional expectations of a Physics course. Changes which may render a course more palatable and meaningful for girls will not necessarily elicit a better response from students and may even produce some antagonism from those who feel that the level of the course is too low. Students who think that a subject has been devalued may opt for other courses, or even for another school which offers a more 'high-powered' approach. In response to direct pressure from the Government and Education Department, the secondary college system in the ACT is becoming increasingly competitive and entrepreneurial. A 'high academic standard', as perceived by the community, is certainly a winning formula in the fight for student enrolments. The introduction of a new approach as outlined in this paper must involve some education of both students and the community as to its educational value.

Assessment in our Physics course has chiefly relied on multiple choice tests and quantitative problem-solving. Evidence indicates that this method of testing and assessing does not suit girls (Harding, 1979). Kearney and MacDonald (1987) suggest that other types of assessment should be adopted and our own results show that girls do indeed respond more positively to non-test based assessment. For example, students were asked to identify assessment items they did and did not like. Few of them selected tests as a favoured option. About 50% of girls stated that they did not like tests (Fig. 8) while a similar proportion stated that they liked the written assessment items (Fig. 9). These items included essays and a precis of a scientific article. Our experience further shows that girls perform well on written items, as they do on practical tasks needing precision in handling of equipment and data. We have observed that the response of many students (boys in particular) to written work is very negative. Sometimes it takes the form of a resounding "But this is Physics, not English!". It is our impression that many students do Physics to avoid written work and feel betrayed when some assessment is based on written tasks.

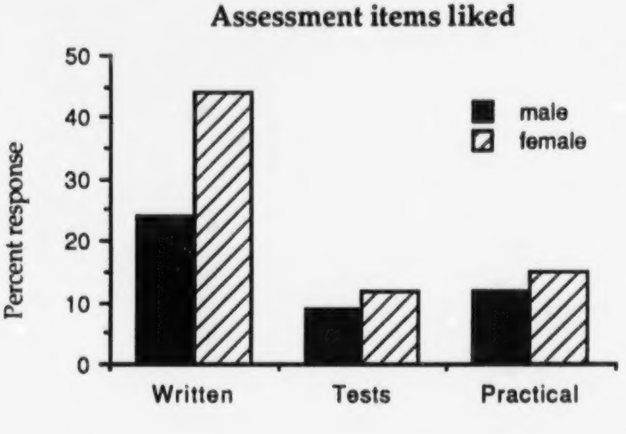


Figure 9 - Students were asked to list assessment items they liked.

One of the requisites of our assessment system is to generate course scores to rank students for tertiary entrance. The students who aspire to places in highly sought-after fields such as Economics, Law and Medicine must be ranked in the top few percent of the population. This puts pressure on teachers to assess students in such a way as to separate these top few percent. Essay type and long answer questions, regardless of their educational value, give difficulty in distinguishing between the scores of 'high flyers'. Tests regarded as "objective", comprising short answer or multiple choice items with one correct anwer, are used to provide a good spread of marks. Unfortunately, a good spread of marks requires a test which is overwhelmingly difficult for the bulk of students. This system of assessment is prevalent in Physics, and is the norm in Mathematics 1. The selection of a small minority of students for a few competitive tertiary courses has an inordinate influence on our assessment procedures. Furthermore, the highest tertiary entrance scores are often achieved through Physics and Mathematics 1 and although girls, in general, perform well in these subjects, they rarely capture the highest scores. This may relate to the observation that girls are under-represented in occupations which have the most significant status and financial rewards: business and commerce, medicine, law, engineering and technology (Commonwealth of Australia 1989). Do some girls miss entry to some of these professions owing to their failure to achieve top rankings in Physics and Mathematics tests which actually have little or no relevance to their capacity to excel in these occupations? In the ACT there are certainly enough girls studying Physics and Chemistry at a senior secondary level to provide adequate representation in these professions.

Teaching Physics Conceptually

The Physics course at Dickson College has in the past relied heavily on equations and their derivations, combined with a lot of practice at plugging data into these equations to produce numerical answers. Granted that our assessment always involved some written and practical components, the ability to manipulate equations remained the most assessed and valued skill.

It has become well accepted that this type of approach does not suit girls. Actually, a concern that it was bad education for all students was our primary motivation for change. We first attempted to modify our assessment so as to test concepts rather than equation manipulation before being introduced to Paul Hewitt's Conceptual Physics course. His principal rule is CONCEPTS BEFORE COMPUTATION and his advice is that no first Physics course should contain much mathematics. According to Hewitt, this approach should allow the teaching of Physics to stimulate students' higher level cognitive skills. The use of students' personal experience in the everyday world is maximised by resorting to English and not maths. The text incorporates few equations and makes a point of showing gender-balanced examples from everyday life. To quote the author: 'Because physics has always been an excellent way to teach mathematics, it has been used for that purpose. But physics can serve a higher purpose - to teach students how to THINK! There are very few courses that teach thinking; Conceptual Physics is one of them' (Hewitt, 1987, p.1). He adds a warning, however. Teaching physics conceptually is much more difficult than teaching it mathematically. Our experience suggests that this is no exaggeration. This is the first year our students have used the Conceptual Physics text. This has enabled us to apply Hewitt's methods more effectively. The experience has been very much a learning process shared by teachers and students alike. In the meantime, we frequently find ourselves resorting to old ways. The result is that test components of our assessment are not always a good reflection of the 'conceptual' nature of our course. There are still occasional concerns that we need to include more 'real physics'.

Should More Girls Do Physics?

While it is undeniable that girls are under-represented in our Physics course at the moment it is difficult to determine what a satisfactory participation rate might be. Whether we should be aiming at matching the 40% of boys who include Physics in their tertiary packages would probably be questioned by some (Willis, 1991). This appears to be a very high percentage given the immense variety of courses offered at secondary colleges in the ACT. At Dickson College alone there are six different tertiary accredited science courses. There seems to be little criticism of the boy who achieves a tertiary entrance based solely on Mathematics 1 and Physics, and little praise for the girl who achieves the same using a broad range of subjects including Mathematics, Science, and Humanities. Equal participation rates of girls and boys may be desirable, but should they be achieved through an increase in the participation of girls, a decrease in the participation of boys, or a combination of both?

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Note 1. R. S. Cameron, 'Student Choices', paper presented at ASERA conference, Melbourne, July, 1989.

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RESEARCH NOTES

PRESCHOOL CHILDREN'S INTERESTS IN SCIENCE

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ABSTRACT

Studies of children's attitudes towards science indicate that a tendency for girls and boys to have different patterns of interest in science is established by upper primary school level. It is not know when these interest patterns develop.

This paper presents the results of part of a project designed to investigate preschool children's interests in science. Individual 4 - 5 year-old children were asked to say what they would prefer to do from each of a series of paired drawings showing either a science and a non-science activity, or activities from two different areas of science.

Girls and boys were very similar in their overall patterns of choice for science and non-science items. Within science, the average number of physical science items chosen by boys was significantly greater than the average number chosen by girls ($p = .026$). Girls tended to choose more biology items than did boys, but this difference was not quite significant at the .05 level ($p = .054$). The temporal stability of these choices was explored.

Efforts to increase participation in science and particularly by girls in physical science have to counter attitudinal patterns which are already present in children at upper primary level. Studies in Australia (Parker & Rennie, 1986) and overseas (Ormerod & Wood, 1983; Kelly, 1986) show that the tendency for girls to prefer biological areas of science and for boys to be more interested in physical science topics is clearly established in children in grades five and six. These attitudes are not a result of formal science teaching received at secondary school.

When these attitudes form, and what factors influence their formation, is not known. Although gender is a very important variable influencing attitudes towards science in secondary and upper primary students, the picture in younger children appears to be largely unexplored. As part of a project to examine the development of children's attitudes towards science, I am investigating preschool children's patterns of interest, to see whether children of this age show any preference for science or non-science activities, and within science, for biological or physical aspects of science.

The first task is to design an attitude measuring instrument suitable for use with preschool children. This initial work is being done with children from two preschool centres, both fairly 'typical' in their programs, with no particular emphasis on science. One group consisted of 10 girls and 13 boys, the other of 6 girls and 13 boys. All children were between 4 and 5 years old. Because I wanted to look at children's preferences, I used a forced choice method where the children were asked to choose which activity they would rather do from a limited range offered. There were 6 sets of activities, with 3 activities in each set; one with a biological science focus, one with a physical science focus and one with a non-science focus. For example, one set was:

> "What would you rather do? Would you rather help set up a fish tank, help set up a torch, or help set up a cubby house?"

This was to try as far as possible to ensure that children were choosing on the basis of the conceptual content, e.g. fish tank, torch or cubby house, rather than on the context of the activity which was helping to set something up. Pictures of the activities were used to try to avoid any difficulties associated with auditory memory. The pictures were presented in pairs, with children being asked to make a 2-way choice of what they would rather do from each combination in a set. The order of pictures from biological, physical and non-science categories was varied within pairs and between pairs.

Results are shown in Fig. 1. Girls and boys were very similar in their overall patterns of choice for science or non-science activities, with a non-significant tendency for both girls and boys to prefer non-science activities. There was, however, a qualitative difference in the types of science activities chosen by girls and boys. The average number of physical science items chosen by boys was significantly greater than the average number chosen by girls (p = .026, 1-tailed t-test). Girls tended to choose more biology items than did boys, but this difference was not quite significant at the .05 level (p = .054).

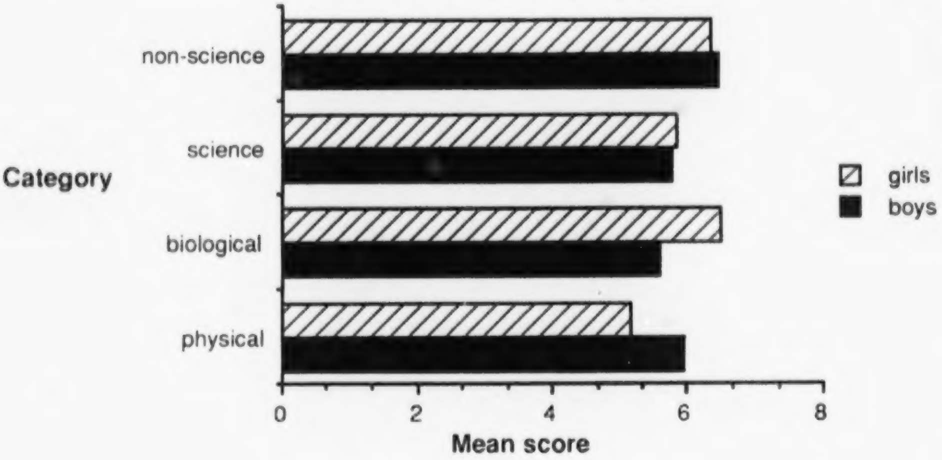

Fig. 1 Category choices made by girls and boys

As one way of assessing the reliability of the test, it was readministered to one group of children after eight days. For individual children, the correlation coefficients between test and retest choices varied enormously, from +0.67 to -0.29. For the whole group the test-retest correlation was +0.07. This could indicate that the test was hopeless, or it could indicate that the patterns of interest in these very young children were very unstable, varying from day to day, or at least from week to week. To test these alternative explanations, I altered the presentation of the test so that all three items in a set were presented at once and the children were asked to choose which of the three activities they would rather do. With this method the test-retest correlations for individual children increased considerably, varying from just above zero to +0.75, and for the whole group was +0.74. This finding suggests that the preferences of the children may be more stable than was indicated by the original method of testing. Initial results indicate that the same basic patterns of interest shown by the two-way testing are present.

There is still, however, a very wide range in test-retest correlations, suggesting that individual children vary in the stability of their choices. Interests could fluctuate depending on recent experiences, and test responses could be influenced by how close it was to snack time or other factors affecting motivation. Following refinements to the test, I plan to further explore the temporal stability of science interests in young children, and to investigate factors which may influence the formation of these interests.

IMPLICATIONS

Although this work is still in its very early stages, it appears that at least some 4-5 year old children have already formed distinct patterns of interest in science which parallel those seen in older children. The common practice in preschools tends to be to allow children to choose the activities they wish to be involved in. This practice could be reinforcing gender differences in science interests. A more interventionist strategy may be desirable, both in terms of the types of activities offered and in encouraging children into those activities, if greater participation by girls in physical sciences is to be achieved.

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PREDICTING ACHIEVEMENT OF FIRST SEMESTER UNIVERSITY SCIENCE STUDENTS

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ABSTRACT

This paper reports on 11 measures used as predictors of students' achievement in their first semester subjects. The students were enrolled in the same four core subjects of a university general science course. Although a number of statistically significant correlations were found, only one predictor variable, HSC aggregate mark, correlated significantly with each of the achievement variables. One predictor variable entered four of the achievement regression equations, while two variables entered the fifth, accounting for 34 to 54% of the variance.

Copies of this paper are available from Dr. Gibbs, School of Applied Sciences, Charles Sturt University - Mitchell, Panorama Avenue, Bathurst, N.S.W. 2795.

Research in Science Education 1991, 21, 349 - 351

THE CONSTRUCTION OF AN ABORIGINAL SCIENCE BIBLIOGRAPHY

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ABSTRACT

This research note concerns the construction of a bibliography of written materials about Aboriginal science and technology drawn from books, theses, dissertations, scientific and non-scientific journals, conference papers and newspapers etc. in fact, articles about the science and technology that relate in some way to Aborigines, from whatever source, have been included. The articles collected have been listed and classified using Hypercard and major issues and themes have been drawn out of these classifications. It is hoped that the bibliography will be of value in itself and that the categorisation of written materials will help curriculum developers.

INTRODUCTION

The purpose of this paper is to explain the way in which the Aboriginal science bibliography was constructed and to indicate how it can be used and to whom it may be useful. The bibliography is a listing of some three hundred and fifty references which relate to Aboriginal science from a wide variety of sources. This should prove useful in itself, but to add to its usefulness as a resource the bibliography has been transferred to Hypercard. Most of the items referenced have a brief annotation and are classified in a number of ways. This should add to the use of the reference for curriculum developers or teachers considering using the "two ways/both ways" approach. The bibliography will thus be available in either as a listing of references or on Hypercard with the references classified and annotated.

CONSTRUCTION

The references were collected by a variety of methods including sorting through all available issues of journals likely to contain pertinent information, collecting references from the reference sections of articles about Aboriginal science and searching conference proceedings of a wide variety of Australian conferences. The usual yearly indexes were utilised and computer searches have been made using the Australian Educational Index (AEI), the British Educational Index (BEI) and Educational Research Information Centre (ERIC), but these searches proved to be of very limited value in this subject area. This search has now taken a little over two years. Initial results after less than a year were published (Palmer, 1990) and in another paper some brief comments were made about the lack of research interest in Aboriginal science: "Aboriginal science is very much a neglected topic" (Palmer, 1991).

The construction of a standard bibliographical listing needs no explanation, but for the hypercard listing a number of additional classifying systems were used. These and the reason for them will be explained. The idea of "two way direction" has been included as a number of educators believe that the "both ways system" is effective in teaching Aboriginal children. In this approach Aboriginal content may be taught using western methods and conversely western content may be taught using Aboriginal methods, but teachers try to avoid using new/western methods to teach new/western content. Within school contexts the use of these approaches would be under Aboriginal control, within the communities. For the purposes of the bibliography the approach has been simplified so that the symbol A>W indicates that the content or method being described is largely Aboriginal, whereas the symbol W>A indicates that the major part of ideas in the article are western.

In a number of cases the classification could be a subject of further discussion. Overall the aim would be to indicate roughly to curriculum developers which areas had a large Aboriginal content, or were approached from an Aboriginal view point.

The author sought wide overall headings which would include large parts of both western and Aboriginal science. The headings chosen were: Education, Technology, Ownership. Taken with the "two way direction" this provides a total of six different classes which the author hopes will be found useful in sorting out similar areas. Fig. 1 illustrates schematically the overall classification system. In Fig. 1 the area in common between the two circles representing the western view of science and the Aboriginal world view (though here and throughout the paper it might be more accurate to say "a western perception of an Aboriginal world view") respectively, is the content area most likely to be a source of science content for mixed or for Aboriginal schools. This domain has within it three common areas called Humanity and Technology, Humanity and Education and Humanity and Ownership. These would be topic areas around which a common curriculum could be constructed. The contents of the bibliography will also be divided into these areas, though it must readily be admitted that some references do not fit naturally into any of the categories, whilst others might well fit in more than one category. Fig. 1 and Table 1 together indicate the way in which the references which have been collected have been classified.

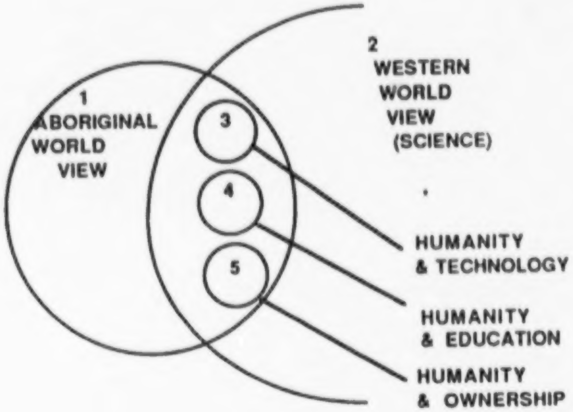

Fig. 1 World views, Aboriginal and western with respect to science.

Table 1 shows generally how the topics fit into particular categories, though it must be remembered that topic areas could be in the A>W or the W>A category depending on the way in which the article was written.

TABLE 1
KEY TO CLASSIFICATION OF REFERENCES

MAIN THEMES	A>W	W>A
Humanity and Technology	Aboriginal material culture Boomerang Digeridu Canoes Fishtraps Bush-medicines	Housing design Bush latrines Appropriate technology
Humanity and Education	Land conservation	Primary curricula Secondary curricula Tertiary curricula
Humanity and Ownership	Land Body/skeletons Drugs Petrol sniffing Diet	Mining Uranium Gold Diamonds Manganese Aluminium Cape York space station Western medical help Atomic bomb testing

CONCLUSION

At the start of this project over two years ago, the author was not sure that there would be sufficient material to form a bibliography. There is in fact a wealth of material though comparatively little of it exists within the confines of science education. The bibliography as prepared is far from complete, but it is hoped that, even as it is, it will be of assistance to enthusiastic teachers or curriculum developers. The author would be interested in corresponding with others involved in this area, and would supply the full text of this paper on request.

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POPULARISING SCIENCE THROUGH TELEVISION

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AN INTRODUCTION TO SCIENCE TERRITORY

The genesis of this project (Science Territory) was an idea of one of the authors (BKR) and this was described in an earlier paper (Note 1), though it has taken some years to implement. In brief, the idea was to produce one minute films giving a favourable picture of the applications of science in everyday life linked to an excerpt from science being taught at a local primary or secondary school. Twenty six of these films have been made and these were shown on commercial television in the Northern Territory between 4.00pm and 7.00pm daily, when children in the 9-13 year old age group would be watching. The titles of these films are:

1. Plant sex
2. Swimming Pool
3. Momentum
4. Fuses
5. Bubbles
6. Gas Pipeline
7. Laser and Optic Fibres
8. Microwaves - AUSSAT
9. Sound Waves
10. Cranes
11. Solar Energy
12. Electromagnetic Fields
13. X-Rays
14. Recompression Chamber
15. Barramundi Skins
16. Drag Car
17. Gliders
18. Rainforests and Ants
19. TB -Bacteria
20. Dash - 8 Aircraft
21. Gold and Carbon
22. Oil Rig Wrenches
23. Crocodile meat
24. Drilling Mud
25. Radiation
26. Remote Sensing

EVALUATION

It was hoped that these children would be interested in the films and parents and children might talk about what they had seen which gave a favourable image of science and science teaching in the Territory. The project had two main objectives which were:

1. To increase students' interest in science.
2 To present to the public a realistic image of school science.

These aims are ambitious and the major academic problem is to assess whether they have been achieved. Efforts were made to evaluate the success of the project in achieving these aims and the results are summarised in Table 1.

TELEVISION, SCIENCE AND RESEARCH

One interesting feature about Science Territory is that, as far as the authors have been able to discover, no similar project has been attempted in the area of science, so there is thus no literature which is strictly comparable. The project has used the known expertise of the advertising industry and of its research, said by Barlex and Carre (1985) to be 'highly competent', to improve the image of science.

Teachers often complain about students' poor memory for remembering scientific facts. However children do appear to be able to remember TV advertisements. Zielske & Henry (1980) have shown that children's long term recall is improved by "a little and often" rather than "saturation" over a few weeks. Science Territory has had advertisements evenly spread over six months.

TABLE 1
EVALUATION SUMMARY (Note 2)

Evaluation Questions	Summary of Results
Did the programs change students' attitudes towards science?	A small sample of students were given tests before and after the program presentation period to measure their attitudes towards science. There was no evidence to suggest that the programs had any effect on student attitudes towards science. A larger and more detailed study might show some result.
How do teachers regard the programs?	Questionnaires were given out to all teachers in 4 Primary Schools and 1 Secondary School. Teachers criticised some aspects of the programs but were enthusiastic about the idea and the programs in general.
How do parents regard the programs?	Students in one class interviewed their parents and their 2 closest neighbours. The results demonstrated great enthusiasm for the programs among parents and the community generally. Many positive suggestions were made about future plans for the project.
How do students regard the programs?	Teachers were requested to ask their classes if they would complete questionnaires. Students rated the programs informative, interesting and scientific and most thought they gave a fair representation of real school science activity.
How did teacher educators, science academics, science education consultants and mining executives regard the programs?	These groups were sent questionnaires after viewing the programs at meetings attended by the co-ordinator. They were asked questions about the concept. Almost every returned questionnaire in these groups rated the concept very highly. They supplied many comments about the future use of this type of program at a national level.
What sort of anecdotal comment has been gathered?	These were collected by the Science Territory management group in general conversation over the period of production and presentation of the programs. Comments were always positive and enthusiastic and often included constructive criticism. People are generally very interested in the project.

Science Territory has always tried to ensure that the science that it depicts is related to experiences from everyday life. This is also the opinion of Tarleton (1991) who has produced a TV science entertainment series in the U. K.

In an earlier paper one of the authors (BKR) points out that in his view student interest will be the main beneficiary of the Science Territory project (Robertson, 1989) :

> When these programs catch the interest of students, then the benefits for school based education will be enormous. Interest level is perhaps the most important factor in determining what a student learns and raising the level of interest in school subjects is what these programs are about

CONCLUSION

Currently the 26 films in the Science Territory series have been shown to audiences who watch Channel 8 commercial television in the vicinity of Darwin. They are still being shown to audiences who watch Imparja Television. There are no plans at the moment to show Science Territory for any extra time on either Channel 8 or Imparja, once the Imparja programmes are complete. There are plans however to develop materials to complement the programmes, which could be used in schools and there are also plans to repeat the success of Science Territory and to expand it on a national basis to a series of programmes to be called "Science Oz".

This research note has described of the Science Territory project which has attempted to improve students' and parents' attitudes to science. It has also attempted to explain how the issue of determining the effectiveness of the project has been addressed. Overall, Science Territory proved to be an interesting, exciting, successful and worthwhile venture, particularly for the small scientific community of the Northern Territory. It also appears to be unique both in Australia and worldwide. There are therefore lessons that science educators can learn from this about new ways of improving students' attitudes to science.

REFERENCE NOTES

Note 1 An informal paper by B. K. Robertson, & W. P. Palmer, (1990) Popularising Science through Television, Australian Science Education Research Association (ASERA) at Curtin University in Perth, 14-17 July.

Note 2 In July 1991 one of the authors (BKR) sent a full analysis of the data to the sponsors (BHP Petroleum). Table 1 is a non-quantitative summary of the results.

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